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and
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A Dead Horse

We were somewhat astounded when, as the result of a Short Paper competition organised by the London Branch of the Institute of British Foundrymen, a Paper on the subject of apprenticeship training won the first prize. Obviously, it was well phrased, incisive and brought the importance of the subject in proper perspective before the audience. Yet, we felt that the Institute and the industry generally had done more than most for the best interests of entrants to the foundry industry. After all, as a technical body, the duty of the Institute is clearly limited to the supporting of local effort—not its origination, which must come from the district foundries—and also the determination of the standards to be set at the annual examinations and the provision of a nationally-unified certificate of attainment. We have spent as much time as most of those in the foundry industry upon the question of the training of the entrants to the foundry industry and in this connection have had the privilege of meeting some of Britain's foremost educationists and, unlike most amateurs, we are quite content to leave the matter in the hands of these experts. With the passage of time, our ideas become less fixed, and probably we are nowadays attaching less importance to technical specialisation and more to general culture. Nevertheless, for the successful prosecution of industry there must be available a carefully-arranged syllabus which will give to the student well-balanced information covering the broad field of foundry practice. The study should not be so intense or onerous as to exclude the student taking a healthy interest in literature, sport, or maybe languages, economics, politics. The most uninteresting fellow one can meet is the highly-specialised technician who has spent all his time and energy learning all about his profession to the exclusion of matters which interest the bulk of the intelligent population. This is one reason why we have supported the activities concerned with Junior Sections of the Institute, as there is a fair dilution from absolute technicalities. All things considered, the organised sections of the foundry industry have created the essentials for the erection of a complete specialised educational structure capable of catering for all branches of its personnel, and it merely remains for individual effort here and there, personally, either as manufacturer or employee, to avail themselves of its benefits.

Cast-Iron Research

We published in our last issue details of a scheme of expansion designed during the next five years to enable the Cast Iron Research Association to reach and expend for the benefit of the industry an income of £20,000 per annum. Ambitious as this may sound, it is well within the region of possibility, and if, as should be the case, all foundries were organised in representative trade associations, no difficulty would arise. The research expenditure of the Iron and Steel Industrial Research Council is financed by the highly-organised and very representative British Iron and Steel Federation. While, however, the relative smallness of similar associations in the founding industry makes the collection of such an income a matter of approaching individual firms a slow process and necessitates considerable publicity, there are some advantages gained. The manner of financing the B.C.I.R.A. compels a very close connection between the association and members, and makes the work done of very practical value. In fact, the risk is rather that sufficient fundamental and long-range work would not be done. Such risk, if it existed, has been avoided by the very handsome offer made by the Government, and subscriptions which earn such grants, such services, and which do not involve income tax, make the adhesion of founders a very attractive proposition.

We imagine that there will always be a crude heavy ironfounding industry, in which common mixtures are melted in the cheapest way. Such works look mainly to economies in production from research. The last decade, however, has opened up entirely new possibilities for cast iron as an engineering material, made in a controlled way from high-class raw materials. For such a product price is a secondary consideration, and such makers look to research primarily for improvements in quality. It is in this direction that we have noted on many occasions the astonishing progress made abroad, and it is of national importance that some technical body should take charge of British interests in this direction. We therefore seriously commend the support of this Association to all British foundries who do not already support it and express thanks to those who do, whatever their motive, for, regardless of immediate interests, the result is a body of national importance, the potential value of which is heightened by the disturbed state of Europe and, indeed, the whole world.

XUM

Factors to Increase Production in Enamelling Plants*

By BERNARD B. KENT

Probably the five most important factors controlling production in an enamelling plant are:—Plant lay-out; engagement of best type of operators; efficient maintenance staff; cleanliness, and correct lighting. Papers have already been given before this Institute covering plant lay-out and certain specific operations in enamelling, but this Paper deals with the smaller details upon which so much depends and which ensure liaisons between the many operations in the somewhat complicated business of porcelain enamelling. It is assumed, of course, that only materials of the first quality are used.

This Paper is intended to be a kind of "Cook's Tour" through the plant and the points given have all been tested and incorporated in the enamelling division of The Sterling Manufacturing Company. To facilitate this mental tour, a short description of the plant in question is probably desirable.

This enamelling shop was originally laid down for the processing of the firm's own manufactures and was later duplicated so as to avoid any stoppages should any of the equipment become temporarily out of commission. This was again extended eventually to process both sheet iron and cast iron, and still later an entirely separate unit was installed for sheet-iron enamelling and the original plant used to take care of the growth in the cast-iron enamelling. The plant at present can be considered almost essentially

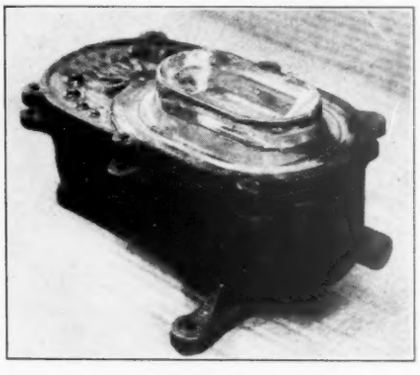

Fig. 1.—Type of Lamp suggested as suitable for Sand-Blast Work.

a jobbing plant, probably as much outside work being done as that of the firm's own manufactures.

Being, as stated, a jobbing plant, it was soon found that a highly efficient storage accommodation was required for the incoming stampings and castings and, wherever possible, a distinctive mark or steel tag is affixed to each unit, and it is the duty of a specially-appointed person to memorise, as far as possible, all items tendered for enamelling.

Cast-Iron Enamelling

Passing to the enamelling plant proper, let us first consider the cast-iron section, the first operation of which is, of course, annealing. Every article, without exception, is subjected to this treatment at a temperature of between 780 and 800 deg. C., special care being taken in the loading of the work to prevent distortion and great importance being attached to the choice of perretts for each individual job.

The next item is blast cleaning, and the choice of equipment or even the type of abrasive used depends on individual requirements and opinion, but, in any case, the essential factors covering production are the same. If more than one type or make of equipment is installed, as many parts as possible should be interchangeable, and this should certainly apply to hose and nozzle holders; it is a good plan to keep a spare unit always ready for immediate change-over in case of breakdown or the bursting of a hose.

There are several types of nozzles on the market but, here again, local conditions enter into this choice, and as the plant in question operates its own foundry, ordinary chilled nozzles are found to be the cheapest.

If possible, the vision windows on all cabinets should be standardised, and it has been found by

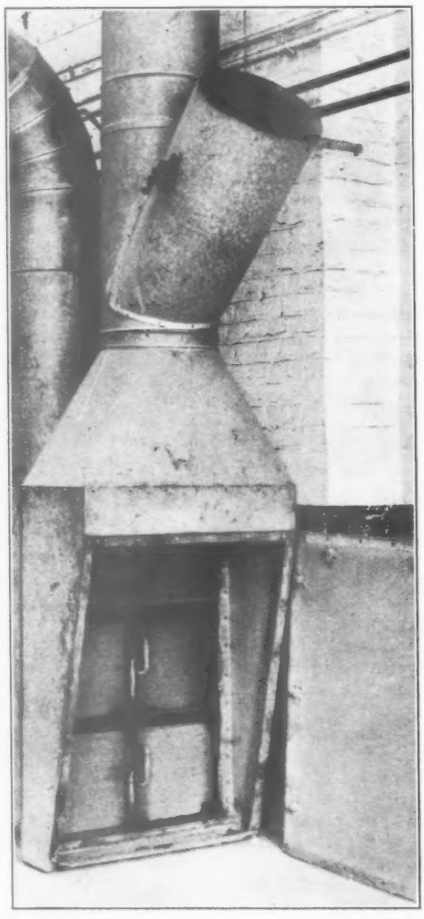

Fig. 2.—Plates carrying Viscous Matter arrest all Dust contained in the Shop Air-Supply.

the writer that a very much smaller window can be fitted with no inconvenience to the workers than that supplied usually by most manufacturers, thus effecting a saving in the cost of glass and wire gauze.

The lighting of the blast-cleaning cabinet is exceedingly important, especially when using steel abrasive, and it has been found that, by enclosing the lamp in bulk-head fittings (Fig. 1), the risk of breaking lamps is reduced to a minimum.

It is, of course, necessary to use suitable protective equipment, and one of the most difficult articles to obtain in this country, in this connection, is a good blast operator's helmet, and the writer is compelled to state that one is forced to go to America for this equipment. The helmet used in this plant is constructed of soft rubber, and is so made that the entire weight rests on the shoulders. Conditioned air is supplied to the helmet through a perforated tube directly over the window, by this means keeping the glass free from condensation, and it must also be mentioned, with regret, that a supplier of gauze for protecting the glass cannot be found on this side of the Atlantic and, although several brands have been tried, the American variety outlasts them about four times. It is hoped that British manufacturers will do a little hard thinking in this direction.

Enamelling Plant

Returning to the plant, great importance is paid to the cleanliness and orderliness. Under this heading is also included the conditioning of the air. It is a whole-time job for one man to be continually sweeping and cleaning the floors, charging forks and equipment, and no person is allowed to enter into the enamelling department unless for a specific purpose. All doors are kept closed as much as possible, and no window is allowed to be opened unless that opening is protected by a muslin screen.

The air-conditioning unit installed is unique in design, and the following is a brief description:—The air is forced through a series of steel tubes passing through the flue of each muffle, and, by trunking, can be blown either into the shop or into the drying room, and, on the intake side, by means of shutters, the air can either be drawn from the atmosphere or from

Fig. 3.—Suggested Arrangement for Spray Booths.

the shop. Before entering the fan, the air is drawn over a battery of viscous filters (Fig. 2).

Trunking also permits the air being by-passed through the heater, with the result that either cold or hot air from the atmosphere can be blown into the shop or into the drying room, and can be either circulated in the shop or drawn from the atmosphere, and, unless the weather is foggy or the air dust-laden, the latter course is usually adopted.

The floors of both plants are marked out with white lines, indicating gangways and positions for work in various stages of its processing. Owing to the fact that the plant undertakes a large variety of work, many different types of drying racks are necessary, but, for the convenience of handling, they have all been standardised as to size. To facilitate handling and identification, each different type of rack bears a distinctive mark, that is, all those having knife-edge supports are painted on the end with a green line and all those having nail-points with a red line; plain racks have a yellow line,

* A Paper read before The Institute of Vitreous Enamellers, Dr. Mellor, F.R.S., presiding.

and a similar distinctive colour for each different type.

A lad is employed to be continually re-stacking and collecting these racks, and a space is marked on the floor for damaged ones. Those found in any way defective are placed in this position, and are collected daily by the saw-mill for repair or scrapping.

The Sprayline

Each spray booth is a separate unit, and is constructed of galvanised iron with detachable baffles, and these are thoroughly cleaned and washed after each shift, and scrapings are removed at intervals in specially-marked containers and returned to the mill room. Each spray booth is provided with a steel turntable, about 14 in. in dia., revolving on roller bearings (Fig. 3). This turntable is perforated with holes about 1 in. apart, into which are fitted loose pointed steel studs. No personnel items or tools, etc., are allowed to be placed on or in the spray booth, and a separate rack is provided underneath each booth for this purpose.

Fig. 4.—A Cupboard is affixed at the End of the Spray-Booth Line for carrying the Guns.

It can be mentioned, in this instance, that individual lockers are provided for each operator, and, in fact, all operators in the plant, to keep such items as rubber gloves, mitts, caps, overalls, filling knives, etc. In both sheet-iron and cast-iron plants, a glass-doored cupboard is provided at the end of each sprayline having hooks bearing numbers corresponding to the spray guns in use, and at the end of each shift the guns are returned to the person responsible for their cleaning and placed in their correct position in the case ready for the next shift, as is shown in Fig. 4. Each spray booth is fitted with a movable light on a long flexible arm and can be directed to any position required in the spray booth.

Great importance should be stressed on the maintenance staff. Engineers should be available in case a breakdown occurs, and spares should be kept for these emergencies, such as spare tools, exhausting fans, fuses for either power or light circuits, etc.

Fig. 5.—Shows the orderly Grouping of Parts to be Enamelled.

Passing from the sprayline, the next factor having a distinct bearing on production is the orderly manner in which the racks of sprayed castings are stacked prior to fusing, and Fig. 5 shows how all castings of a type are grouped and the stacks of racks are placed regularly. These racks of sprayed castings are removed from the drying room immediately they are dry, so as to keep that room as free as possible for incoming work.

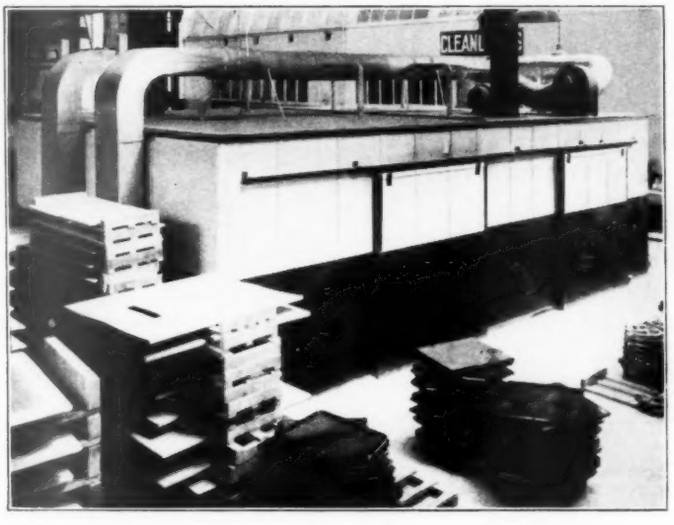

Fig. 6.—Shows the Air-Circulation System of the Drying Room.

Drying-Room Details

The construction of this drying room may be of particular interest; it is heated by the waste gases from one of the muffles being zig-zagged under the floor before passing through the chimney. Fig. 6 shows the air-circulating arrangement, the air being drawn out from the bottom at each end by a Sturtevant fan and blown in through a large number of openings in the roof. By this means, a whirlwind of hot air is produced, and rust spotting is completely eliminated.

It is found impracticable to keep the door between the blast-cleaning department and the enamelling shop closed owing to the continuity of work passing out, and to avoid dust from this department a long enclosed corridor has been constructed, and an exhaust fan ensures that there is always an excess of air in the enamelling department, sucking back dust that may escape into the passage.

Enamelling Ovens

The burning equipment in this plant consists, at the present moment, of two muffles, which are worked by oil and two heated by gas. In the light of experience, all muffles will eventually be changed over to town gas, owing to the many advantages which counteract the slight extra cost of this fuel. Fig. 7 shows the special type of furnace operating on gas and constructed of a series of tubular arches running underneath the landing walls. Each of these tubes is heated by gas burners, there being eight in all. Apart from the extreme flexibility obtained by using gas, temperatures can be more closely controlled,

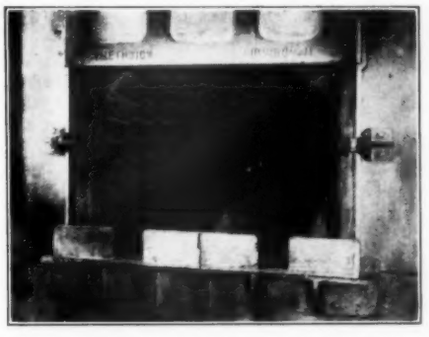

Fig. 7.—Showing the Tubular Roof-Bricks and the Special Fire-Hearth Castings on the Gas-fired Stove.

and it is unnecessary to build up a very high temperature in the combustion chamber to obtain the normal heat in the muffle. It is also possible to increase the temperature by about 200 deg. in less than 2 hrs.

As a safety precaution, furnaces burning oil are coupled together, and an emergency oil supply is kept underground. Should, therefore, for any reason, the main oil supply fail, it is possible to switch on the emergency supply, thus preventing any stoppage of work.

It may be of interest to know that for muffle single loads the gas consumption is in the neighbourhood of 1,300 cub. ft. per hr., while for hanging loads or double- or treble-decked loads the consumption is in the neighbourhood of 1,850 cub. ft. per hr. When annealing at high temperature, this consumption necessarily rises, and is approximately 2,100 cub. ft. Fig. 7 also shows that on the front a specially-constructed casting is bolted, which serves a double purpose of preventing the damaging of the landing walls by careless operation of the charging fork and conserving heat losses.

Fig. 8.—Illustrates the Type of Perretts used for Double and Multiple Decking.

The charging of these furnaces is, of course, operated by double forks, but it has been found that far more rapid handling can be accomplished by uncoupling these forks and operating as single units rather than as usually supplied by the manufacturers. Fig. 8 shows a close-up of special perretts constructed for decking, and these, of course, can be used for either two or three layers of work. Another small item effecting production is the installation of compressed airlines to each muffle for blowing off castings prior to firing, and Fig. 8 also shows one of these lines in which is inserted an air purifier to ensure that dry air is used.

Mill-Room Management

In the mill room, great accuracy is insisted upon, and every batch of enamel milled is entered in a log book and given an appropriate number. Fig. 9 shows a specimen page of this book. Particular attention is paid to a colour control, and a piece of ware is fired in the small gas muffle, shown in Fig. 10, to check up with the standard colour sample. It will also be noticed that all oxides and other chemicals needed for control are kept in glass-stoppered bottles. No enamel is allowed to be stored in any of the bins unless it bears an accurate description and a reference to the mill-room log book.

Owing to the large number of different colours that are, from time to time, used, a sample plaque is fired with each colour and bears the exact formula or reference to a formula number fired on the back thereof. It is now, therefore, nearly always possible to match a customer's colour sample by comparing with one of the existing control plaques. This saves the necessity of experimenting to obtain the exact colour.

Considerable trouble was first experienced when starting out on this plant with the choking of gulleys and drains by waste enamel. This has been overcome by constructing a sump hole from which all washing stations lead. This sump is cleared daily, and the sludge passed over magnetic separators and an electric sieve, and it is now possible to re-frit this waste. As a matter of fact, the frit produced is of exceptional quality, which may seem strange in view of the fact that it contains all types and kinds of enamel, from ordinary sheet-iron ground coat to acid-resisting cast-iron enamel.

Compressed-Air Line Maintenance

Another factor helping to maintain continuity of production is a kind of switchboard through which all compressed-air lines are passed. Each of the six compressors is fitted with three relief valves set at 40, 70 and 120 lbs. per sq. in. pressure, and by means of this control board it is possible, by merely adjusting valves, to couple any compressor at any pressure through any blast-cleaning apparatus or spray line. Thus, a breakdown with one compressor has little, if any, effect on the production in the plant.

Other sections of plant do not possess any distinct features, and the pickling, swilling and inspection and passing-out benches all conform to the usual practice. Every endeavour is made to interest the staff in the work in which they are engaged, and all current literature published on enamelling is always available for perusal. In this connection, The Institute of Vitreous Enamellers can do a great work by increasing the operators' interest in their daily job.

DISCUSSION

Mr. A. England asked if the air drawn from the drying room was re-used in the whirlwind or whether it was exhausted to the atmosphere.

Mr. Kent replied that the air was re-used.

Nozzle Wear

Mr. Kenneth Hill, referring to the blast-cleaning equipment, asked if it were not a fact that, as the nozzle wore, a great deal more air was used, thus increasing the costs. Secondly, he asked what was the source of the blast operator's helmet referred to in the Paper. And, thirdly, how the air entering the helmet was conditioned.

Mr. Kent replied that the Sterling Company did not allow the blast-cleaning nozzle to wear very much; they cost very little, and they were changed very frequently. The helmet he had referred to was a Pangbourn helmet; although the Sterling Company had tried every make they could find, they had never seen another helmet anywhere like it. The air entering the helmet was really super-conditioned, various contrivances, including purifiers and scrubbers, being employed to keep the air clean and dry.

Mr. J. G. Roberts asked if Mr. Kent had tried the new hard-steel nozzles. They were used both in the American and the British factories of the Singer Company, who were particularly keen on effecting small economies in production; he believed the cost of every item of production in the British factory was compared with the cost of the same item in the American factory, and they had stated that the new hard-steel nozzles were much more economical than the nozzles which the company had previously made for their own use. His company also was using them, but the experience was not sufficiently extensive yet to warrant too definite an expression of opinion. However, to get 70 blasts per nozzle, costing 2s., was good economy. Another nozzle, *i.e.*, the boron carbide nozzle, was said to give many hundreds of blasts before a change was necessary.

Date Mill No.

Batch Colour

FRIT	WEIGHT
Clay	
Oxide	
Oxide	
Oxide	
Water	
Composition	
Composition	

Mill started at

Mill stopped at

Amount of Scrapings added

Ground to Units

Fig. 9.—Specimen Page of Mill Room Log-Book.

Fig. 10.—Experimental Muffle for Colour-Matching is installed in Special Material Stores.

(Concluded on page 260.)

The Technique of Chilling*

By J. ROXBURGH

It is proposed to deal with chilling and densening, as it is well known that there is a definite demand for chilled castings in modern industry, and, also, densening is becoming increasingly favoured by manufacturers of specialised castings. So, initially, attention should be directed to the "chilling irons" and to the consideration of why these irons, under certain conditions, are able to throw a chill on a casting. It is generally accepted that certain irons possess this property to a greater degree than others, and cold-blast iron, which has a very wide application in the manufacture of chilled rolls, is a notable example.

It is, of course, generally understood that certain grey and mottled irons, when poured into an iron mould, will "chill," and it is found from experience that, when the silicon content is approximately 1.7 per cent. in an ordinary iron containing up to 0.9 per cent. Mn and 0.1 per cent. S, a bare chill will be shown on a test-piece, cast on a chill, and that, as the silicon is reduced, so the depth of chill is increased, until with approximately 1 per cent. silicon, for example, a chill of $\frac{3}{4}$ in. could be obtained. It is also recognised that silicon is the most important factor governing the amount of combined carbon present in an iron, and, for this reason, may be said to be the chief constituent in determining the depth of chill as revealed on a test-piece.

To the uninitiated, it would be perplexing to know how to set about obtaining a chill, and so, considering an iron with a silicon below 1.7 per cent., a chill could be thrown when the iron is:—(1) Low in total carbon, in which case such an iron has a higher initial freezing point and consequent less separation of graphite; (2) high in sulphur. The carbon is therefore retained in the combined form by the portion of sulphur not associated with the manganese, and it is that portion which crystallises with the carbide, which is mainly responsible in preventing the separation of graphite by making the carbide stable; (3) low in silicon. As stated above, the silicon, as it is reduced below 1.7 per cent., gradually increases the chilling properties, due to the lesser dissociation of the carbide into graphite and pearlite; (4) high in manganese. Above 1 per cent. manganese tends to keep the carbon in the combined state and form carbides, thus accentuating the chilling properties of the iron; and (5) high in chromium. It appears that a double carbide of iron and chromium is formed with a hardening effect on the iron, which tendency is also noticed particularly in the chilling proclivities of the metal.

Thus, it is obvious that, in the above five examples, it is possible to obtain quite different types of "chill," and the chilled surfaces are definitely of a different character in regard to microscopical structure and physical properties, and must therefore exert considerable influence on the behaviour of the castings in service. For instance, with a low total-carbon chilled iron, it is possible to obtain a surface hardness of only 50 Shore, whilst, with a high-sulphur chill, up to 0.2 per cent., the Shore reading can be 70. Again, with high manganese, above 1 per cent., figures of the magnitude of 65 to 70 Shore can be obtained, and with chilled iron, containing sufficient chromium, readings of 80 Shore can be reached.

The Back of the Chill

It is all very well being able to obtain a chilled surface on the casting, but, at the same time, too great emphasis cannot be laid on the importance of the resultant background. It will therefore be appreciated that each of the above elements exerts its own individual effect on the background of the structure. It is found, for example, that with a low total carbon, the chilled portion is usually backed up with a depth of mottle, gradually merging into a dark grey background, all denoting strength and toughness.

On the other hand, with shallow high-sulphur chills, a very defined chill is obtained, with very little mottle between the white area and the background, while with deep chills there is a tendency to be mottled throughout. Such a structure definitely lacks strength, and is of a brittle nature. In the case of high-manganese chills, the manganese tends to increase the strength of the iron, and also the resistance of the castings to heat strains, and hence diminishes the danger of surface cracks. An interesting application of a high-manganese chilled casting is one where the casting has to withstand repeated impact, *e.g.*, crusher jaws and hammer pellets. The chill produced with high manganese extends deeply into the juxtaposed grey portion.

Chromium Chill

With regard to a chromium chill, the carbides appear to penetrate into the background in streaks, and if the chromium content is high, these white streaks extend very often to the centre, where they seem to form a cluster. These streaks definitely weaken the background, and, in order to increase the strength of the iron, it is customary to add molybdenum or nickel, or both, to eliminate the mottle in the background. Naturally, the depth and quality of chill required on a casting depends on the service for which it is intended. Many different depths and types of chill are therefore required on chilled rolls; in the case of strip rolls, sheet rolls, tinplate rolls and plate rolls a depth of $\frac{5}{8}$ in. to $\frac{3}{4}$ in. is good practice, as a particularly strong roll is demanded. For hot breaking-down rolls, where a good finish is not so essential, a low total carbon, approximately 3 per cent., and fairly low sulphur, is suitable, as such a roll is able to withstand temperature and shock. On the other hand, for cold finishing, a much harder surface roll is required to obtain a polished surface on the rolled material, and to-day, alloy rolls are more in fashion, whereby, with the addition of chromium and molybdenum and nickel, Shore hardnesses of the order of 80 are obtained. In this connection, it may be mentioned, it is possible with alloy-steel rolls, suitably heat-treated, to obtain regularly figures of 100 Shore.

Chill Depths for Various Uses

With section rolls, the depth of chill varies according to the size of roll and the section to be rolled, so variations of chill from $\frac{3}{4}$ in. to as much as $2\frac{1}{2}$ in. are asked for. As the sections are generally machined out of solid, the hardness decreases in the bottom of the grooves, but at the same time a fairly strong roll is required. High-sulphur rolls are extensively used for section rolls where there is no great temperature or stress on the rolls. Caution must be exercised, as, if the roll be brittle due to a deep chill and too high sulphur, cracking or premature breakage may occur. For very deep sections, a low total-carbon, low-silicon and lower-sulphur iron has proved better in service. With wire rolls, with small grooves, and consequently little stress, a deep chill is used with confidence, and a sulphur content of 0.2 per cent. would prove quite safe in service.

For rolls of rubber, linoleum, paper, seed, flour, etc., generally speaking, a maximum of 1-in. chill should be aimed at when they are solid, but for hollow rolls $\frac{3}{4}$ in. is ample. Where refining of material is carried out under pressure, a much stronger roll is required, and $\frac{1}{2}$-in. chill is quite sufficient. In connection with paper, seed and flour rolls, a hardness of 72 Shore is demanded by the customer, and, with the small-diameter rolls, this can be achieved by the use of a suitable iron, with high total carbon in the region of 3.6 to 3.7 per cent., as the main feature, whilst, particularly in the case of paper rolls, which are usually of great length with a wide variation of diameter, alloys are resorted to, mainly chromium and nickel or molybdenum. The surfaces of such rolls must be extremely hard, high polished and absolutely free from pinholes or any defects whatever.

Effect of Thermal History

The ultimate physical and microstructure of cast iron depends not only on its composition, but on the cooling rate, and, by the acceleration or prolongation of this cooling rate, so will result different structures. With chilling, the cooling rate is artificially accelerated, and, in the case of the formation of an actual depth of chill, the iron is frozen immediately, all the carbon in the white area being retained in the combined form, whilst, with densening, the time for the separation of the graphite into large flakes is curtailed, with the result that the graphite formed is in a finer state of division. So that, in the main, it is the form in which the carbon exists after chilling which is the important feature, and the effect of the other elements in the cast iron is shown in their influence on the stabilisation or otherwise of the carbide, and also, due to their presence, the actual degree of hardness of the surface may vary.

In a chilled roll, there are three different zones, the white zone, the mottled zone and the grey background. Tensile strains are set up after solidification has commenced, due to the difference in contraction between the three types of iron and the different temperatures obtaining in the three zones, and also it is accepted that graphitisation takes place with expansion, and for these reasons it is important that the white area formed should be strong enough and set quickly enough to resist all these forces. Sometimes vertical cracks are found on a chilled roll, after removal of the casting from the mould, and these are attributable definitely to metal, and are very often due to "uneven chill" on the roll, cracking taking place where the chill is shallowest. On the other hand, a horizontal crack points to some obstacle due to moulding practice, to the vertical contraction. If, for instance, two chills are used to form the length of a roll, cracking at times is found at the joint, and this defect might be traced to the fact that the top chill has not been set correctly at right-angles to the bottom chill, or might be slightly larger, or it is possible for the top neck even to cause interference with contraction due to a swell on it or to insufficient taper having been allowed, or again to not having been "eased" soon enough.

Again, if an iron has too long a freezing range, and certain constituents are present in a larger percentage than usual to cause graphitisation, it is possible for such an iron to continue "working" inside the mould for a long period, with the ultimate effect of causing graphite spots to be formed well into the white area, and, particularly in the case of irons, fairly high in manganese up to 0.7 per cent., on machining the surface of the roll, graphite spots can be detected on the chilled surface itself. It is usual, therefore, in chilled rolls to have a low-manganese iron or one with a manganese content above 1 per cent. to obtain a definite fixed chill.

Effect of Elements on Chill

It is now necessary to consider the effect of the various constituents on the depth of chill

* A Paper read before the Sheffield Branch of the Institute of British Foundrymen, Mr. J. E. Hurst presiding.

as indicated on a chilled test-piece. From experience, it has been found that the lower the total carbon, the deeper the chill thrown, and, following from that the raising of the total carbon will cause a reduction. Again, all other constituents being constant, the lower the silicon, the deeper the chill, so that in the event of the chill depth, as shown on the test-piece, manganese, a similar chill could be obtained. Phosphorus, incidentally, has very little influence on the actual chilling of an iron.

Supposing it is desired to obtain, for instance, 1-in. chill on a test-piece, it is submitted that this can be done with, for example, eight different mixtures of iron and ultimate compositions of irons, as set out in Table I.

Table I.—*Mixtures for a 1-in. Mill.*

Cwts.		T.C.	Si.	Mn.	S.	P.
	(1) *Suitable for a Hydraulic Cylinder.*					
10	Cylinder scrap	3.2	0.9	1.2	0.095	0.4
5	Machinery scrap	3.2	1.5	0.9	0.070	0.6
5	Cylinder iron	2.8	1.0	1.6	0.050	0.3
20	+ 14 lbs. FeMn (80 per cent.)					
	Calculated analysis	3.10	1.07	1.7	0.077	0.42
	Actual analysis	3.20	0.90	1.20	0.10	0.42
	(2) *Could similarly be used for a Hydraulic Cylinder.*					
9	Steel	2.8	—	0.5	0.05	0.05
12	S.S. scrap	3.2	1.7	0.8	0.09	0.50
2	Forge	3.4	1.0	0.9	0.095	1.2
2	No. 4 Comm.	3.3	2.0	0.9	0.05	1.2
25	+ 35 lbs. FeMn (80 per cent.)					
	Calculated analysis	3.08	1.07	1.7	0.073	0.45
	Actual analysis	3.20	0.90	1.20	0.10	0.45
	(3) *Suitable for Chilled Rolls for Sections, etc. Silicon would be altered to increase Depth of Chill.*					
5	Chilled scrap	3.30	0.90	0.33	0.160	0.5
10	Air furnace Iron	2.90	1.10	0.45	0.130	0.40
5	Cold blast	3.40	1.10	0.55	0.090	0.55
20						
	Calculated analysis	3.12	1.05	0.44	0.128	0.47
	Actual analysis	3.30	0.93	0.33	0.160	0.47
	(4) *Suitable for Chilled Safe Plates.*					
10	Swedish	4.0	0.6	0.3	0.03	0.05
5	Chilling Iron	3.3	0.5	0.5	0.07	0.4
5	Cold blast	3.4	1.0	0.6	0.08	0.5
20	+ 35 lbs. FeMn (80 per cent.)					
	Calculated analysis	3.68	0.68	0.43	0.053	0.25
	Actual analysis	3.75	0.58	1.20	0.08	0.25
	(5) *Suitable for Chilled Sheet Rolls, etc., where Silicon would be reduced.*					
Air furnace		3.00	0.85	0.35	0.120	0.50
	(6) *As No. 5.*					
Air furnace		3.00	0.8	0.26	0.08	0 50
	(7) *Limited Application. Small Section Rolls.*					
All chilled scrap		3.40	1.3	0.26	0.21	0.5

(8) *Suitable for some Heat-resisting Castings.*

Cwts.		T.C.	Si.	Mn.	S.	P.	Cr.
8	Steel	2.8	—	0.5	0.05	0.05	—
6	Ingot mould scrap	3.5	2.0	0.7	0.06	0.06	—
6	Hematite	3.8	2.5	2.0	0.05	0.05	—
20	+ 14 lbs. FeChrome (70 per cent.)						
	Calculated analysis	3.31	1.35	1.01	0.053	0.053	—
	Actual analysis	3.45	1.20	0.7	0.08	0.06	0.35

being greater than desired, powdered ferro-silicon or, on the other hand, a definite quantity of soft iron, may be added to the metal in the ladle. The composition of the soft iron, of course, should be known, so that a calculation can be made in order to determine, for example, that 1 cwt. of soft iron, when added to 1 ton of a definite chilled iron, would reduce the depth of chill by, say, ¼ in., or, in other words, the addition of 0.06 per cent. silicon.

An increase in sulphur definitely increases the depth of chill on a test-piece, and, where the test is lower than required, some people resort to adding powdered ferrous sulphide to the metal to increase the depth of chill. This element sulphur must be considered along with manganese, as an alteration of either constituent will influence the depth of chill. An increase of manganese up to 0.9 per cent. reduces the depth of chill, but beyond 1 per cent. a manganese chill is obtained, as explained previously. Thus, it is possible with an iron containing low silicon, low sulphur and 1.5 per cent. manganese, to obtain 1½-in. chill on a test-piece; yet, on the other hand, with a low silicon, 0.15 per cent. sulphur and 0.30 per cent.

Thus there are shown eight different mixtures, varying in analysis from 3.0 to 3.75 per cent. total carbon, 0.58 to 1.3 per cent. silicon, 0.26 to 1.20 per cent. manganese, and 0.08 to 0.21 per cent. sulphur, and one mixture with chromium, and yet all showing approximately 1-in. chill on a test-piece.

Now it is all very well being able to obtain 1-in. chill, or whatever depth of chill is aimed at on the test-piece, but if, in addition, it is required to guarantee a certain depth of chill on a casting, made from such a metal, then here is a matter most difficult of achievement, and the results obtained immediately reveal any discrepancies or variance in the control exercised. In other words, the control of the loss of chill from the test-piece to the casting is of supreme importance, and, before proceeding to deal with this matter in detail, it is proposed to give particulars regarding the test-piece, to which frequent reference has been made.

Making Chilled Test-Pieces

The test-piece itself measures 6 in. by 6 in. by 1¼ in., usually made in a core, and placed on an iron slab, 8 in. by 5 in. by 2 in. thick. This slab is heated, coated with blacking, and then the metal is poured into the test-piece and allowed to remain for 5 min. It is then withdrawn, cooled in the air and finally quenched in cold water. Every care should be taken with the carrying out of these tests, otherwise confusing and indefinite results will be obtained. For instance, the higher the temperature of the metal when cast into the test-piece, the deeper the chill, and so the test should be poured each time with metal at approximately the same temperature. Care, too, should be exercised not to accelerate unduly the quenching of the test-piece, as cracking may occur, and it is also better to allow the test-piece to cool down to a definite temperature before commencing to quench, so that, particularly in the case of deep chills, the depth of chill can be read more easily and a better background to the chill be obtained. In fact, all conditions should be as near standard as possible in order to make the results comparable. This size of chill test-piece is suitable for indicating depth of chill where silicons below 1.7 per cent. are involved.

In reviewing the possible variables which will influence the loss of chill from test-piece to casting, the following suggest themselves for consideration:—(1) Composition of metal; (2) temperature of casting; (3) mass of casting to be chilled; (4) thickness of iron mould; and (5) thickness of blacking applied to iron mould. With regard to composition of metal, which, undoubtedly, is the factor exerting the greatest influence, it can be stated that it is possible for 1¾-in. depth of chill to be thrown on a test-piece by two different mixtures of iron, and yet on the same casting, cast under identical conditions, there would be 1¾-in. chill in one case, *i.e.*, no loss of chill, and on the other ¾-in. chill, *i.e.*, 1-in. loss of chill. A cupola-melted cast iron of the following composition:—Total carbon, 3.3; silicon, 0.85; manganese, 0.32; sulphur, 0.20; and phosphorus, 0.5 per cent., would give no loss of chill, whilst an air-furnace iron containing total carbon 2.90, silicon 0.70, manganese 0.32, sulphur 0.120 and phosphorus 0.5 per cent. would lose ¾-in. chill under the same conditions.

Mn : S Ratio and Loss of Chill

If the total carbon, silicon and phosphorus are constant, it is possible to alter the loss of chill from test-piece to casting by varying the balance between the manganese and sulphur. If the sulphur be kept constant and the manganese content is progressively raised up to 0.9 per cent., the loss of chill from test-piece to casting is increasingly greater, but, on the other hand, if the manganese remains constant below 0.9 per cent. and the sulphur is gradually increased, the loss of chill is diminished. It must be remembered, however, that above 1 per cent. manganese increases the depth of chill on the test-

Table II.—*Influence of Mn : S. Ratio on Loss of Chill.*

	T.C.	Si.	Mn.	S.	P.	Ratio Mn : S.	Loss of chill.
1	3.3	0.8	0.25	0.16	0.5	1.57/1	Nil
2	3.3	0.85	0.32	0.20	0.5	1.6/1	Nil
3	3.3	0.75	0.32	0.16	0.5	2/1	¼ in.
4	2.8	0.70	0.32	0.12	0.5	2.66/1	⅜ in., extra loss due to low T.C.
5	3.3	0.65	0.45	0.16	0.5	2.81/1	⅜ in. to ¾ in.
6	3.3	0.60	0.32	0.08	0.5	4/1	1 in.

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piece, and, as the content is raised, so the loss of chill is diminished.

The six analyses shown in Table II would give approximately 1½-in. chill on a test-piece, but the manganese-to-sulphur ratio varies in each case with subsequent effect on the loss of chill to the casting, as instanced on a 16-in. dia. chilled roll.

The fourth example is an air-furnace iron, and it has been found, from experience, that, if the manganese is raised to 0.42 per cent., all the other constituents remaining the same, it is possible to lose as much as 1¼-in. chill, so that if a deeper chill were required on the roll, it would have to be cast with an iron showing a deeper chill on the test-piece, by lowering the silicon. Lower total carbon gives a deeper chill on the test-piece, but, due to this, it has been found that a greater loss of chill occurs from the test-piece to the casting. If the total carbon is as high, for instance, as 3.7 per cent., the chill on the test-piece is shallower, but less loss occurs in the casting.

Alloyed Rolls

In cases where chromium is added to chilled iron, in order to obtain a similar depth of chill to that of an iron without a chromium addition, the silicon content must be increased. For instance, a 1½-in. chill on a test-piece could be given with an iron of the following composition: Total carbon, 3.4; silicon, 1.10; manganese, 0.33; sulphur, 0.16; phosphorus, 0.5; and chromium, 0.4 per cent. Chromium definitely prevents the loss of chill from test-pieces to the casting, and at times, with higher percentages, the depth of chill has actually increased. Where nickel and chromium are alloyed together in aiming at the same depth of chill on a test-piece, the silicon content should be determined by making allowance for the nickel present.

Molybdenum may be employed as the only alloy present, and a typical analysis of a strip or sheet chilled roll is:—Total carbon, 3.0; silicon, 0.60; manganese, 0.27; sulphur, 0.06; phosphorus, 0.4; and molybdenum, 0.25 per cent. Claims made for this type of roll are that it is stronger, there is less breakage and less frequent dressing, and a better finish on the rolled products is obtained. Molybdenum apparently does not increase the depth of chill, but toughens both the chilled surface and the matrix.

Casting Temperature

With regard to temperature of casting the second variable, this temperature naturally falls within well-defined limits, as "burning-on" would result if the temperature were too high, whilst casting at low temperatures would interfere with running and would cause pinholes, too. For small chilled rolls up to 26-in. dia., a range from 1,240 to 1,270 deg. C. is usual, whilst for larger rolls above 26-in. dia. 1,210 to 1,240 deg. C. is suitable. In any case, the metal should be melted as hot as possible and allowed to cool down to the desired temperature, as badly-melted iron for chilled rolls is fatal and should be scrapped straightaway. It has been shown that the lower limit of casting temperature gives a slightly deeper chill on the casting, but, as it only amounts to about $\frac{1}{16}$-in. increase, this phase of the subject is hardly worth serious consideration. It is, however, best to cast at the higher limit of temperature in an endeavour to obtain a cleaner roll.

Mass and Chill

The mass of the casting to be chilled naturally enters into this question of loss of chill, and so it is found, with smaller chilled rolls, the loss is less than with larger castings, and this is especially marked where deep chills are concerned. With the same iron, when casting, for instance, a 10-in. roll and a 24-in. roll, the latter roll should be cast at least ⅛ in. deeper on the test-piece than the former to obtain the same depth of chill. Regarding the thickness of the iron mould, the first point of importance to be stressed is that it is primarily a question of strength and stiffness, in the case of chilled rolls. Rather err on the thick side, as thin chills in contact with the metal will crack, so that essentially it reduces itself in the first place to having sufficient strength in the mould to take care of the expansion and contraction strains. It must be realised that a very short time after casting, the walls of the mould have no further effect on the cooling of the casting, and that, increasing the thickness of the walls beyond a given measurement has no effect on its chilling. Chills for a 10-in. roll are usually 6 in. thick, whilst a suitable thickness for a 30-in. roll would be 11 in. thick.

The last variable, the thickness of blacking applied to the iron mould, definitely has only a slight effect. The iron mould is usually coated with wet blacking, mixed with molasses, the idea being to obtain a uniform thickness of blacking, as thin as practicable, to adhere to the chill whilst casting. If the blacking is unduly thick, it might affect the loss of chill to the extent of ⅛ in. maximum.

So much for that aspect of "chilling" where an actual depth of chill is obtained on a casting, but, as a result of the study of the details of this practice, there has been developed what are known as "bastard" rolls and "half-hard" rolls. With regard to the former, these are usually cast in the same chills as are used for chilled rolls, but are made from an iron giving only $\frac{1}{32}$ in. to ¼ in. on the test-piece. The result is that the roll itself, on machining, only reveals a skin chill, which, when machined off, shows a very close-grained structure, which penetrates for a depth of 2 in. to 3 in., and is suitable for section rolls, the grooves being machined out of the solid. These rolls are used for breaking down, but are somewhat limited in their application.

A "half-hard" roll demands particular attention to the composition of the iron itself, as well as to the densening effect of the iron mould. For instance, a chill, as used for chilled rolls, could be struck up with ¼ in. loam on its surface, due regard, however, being paid to "venting," and permit of iron giving 1½-in. chill on a test-piece to be used and still give a close-grained iron, easily machined, and densened to a depth of, maybe, 4 in. Likewise, with such rolls with the grooves actually cast, in which case iron bricks approximately the shape of the grooves are built in the mould and coated with a ¼-in. loam, the quality of the roll, depending on the very close structure obtained, is greatly enhanced.

Densening

This principle of densening, by the use of chills of a definite shape and thickness, with a view to obtaining a closer structure of iron in a casting than would be the case by the use of sand alone, has been successfully applied to castings for other industries. For instance, wheel blanks are cast in circular chills and the teeth, when machine-cut are stronger and tougher. Better service is ensured with tyre and glass moulds when cast on a chill. To-day the machine-tool maker often specifies that the slides be densened by chills and goes so far sometimes as to demand specific Brinell hardness numbers.

When all is said and done, if it is appreciated that, in chilled work, iron moulds of at least 6 in. thick are in common use, that it is submitted that, as densening has arisen definitely from the practice of chilling and chilling irons, the principles involved need only be taken the necessary step further to provide the fundamentals for the practice of densening.

Densening is again resorted to where there are different sections of metal to contend with in a casting. What is really important is the acceleration of the period of cooling in some particular place. If one could obtain uniform cooling conditions of both thick and thin sections then the demand for the thin section for more metal from the thick section would cease. With a hydraulic cylinder, for instance, there are sometimes places where large ribs, brackets or feet join the casting, causing abnormal sections of metal and, despite the fact that a low-carbon, low-silicon, close-grained iron is used, the bore, when machined, reveals sponginess in the vicinity of these sections. Such is the sponginess which, very often, can be eliminated by the careful application of denseners. One can also do much, in this connection, by the use of alloys, particularly nickel.

Chill Tests and Machinability

For ordinary dry-sand castings, the chill test, as described, can be applied and prove very helpful, but it is as well to remember that such tests are comparative and can only be correlated where similar mixtures of iron are used and similar compositions sought. Composition is not everything, but is merely a guide, and after all it is the ultimate structure obtained which is the important point. Chill tests are particularly useful where the machining qualities of a casting are of vital importance. For instance, it has been found from experience that an iron containing total carbon 3.2, silicon 1.2 and chromium 0.7 per cent., showing 1⅜ in. depth of chill on a test-piece, would permit of machining of a casting 1 in. thick, cast in a dry-sand mould. Any lowering of the total-carbon content, reduction of the silicon or increase of chromium would render the iron unmachinable with the facilities available in this particular instance. Even with the same mixtures on the cupola, an analysis cannot be guaranteed as the melting conditions vary from day to day and so, in this case, if a chill test be taken, it may be that the depth of chill is in excess of 1⅜ in., and so soft iron may be added to restore the balance of total carbon, silicon and chromium, thereby ensuring the machinability of the casting. If the casting had been poured without viewing the test-piece, a waster would have been inevitable.

Another application of the chill test in dry-sand work, where similar irons are made use of, is the correlation of the depth of chill to section of casting for high-grade work, where as close a structure as possible is demanded. For instance, a casting 3 in. thick would have a better structure when cast with an iron containing 1 per cent. silicon than one of 1.5 per cent. silicon content and a chill test would show 1 in. probably in the first case and only ¼ in. in the second, so that the chill test would reveal the suitability of the iron, before casting, for the particular job. Often, too, the exact nature and analysis of the scrap in the yard is not known, and after incorporating a percentage of this in a definite mixture, a chill test can be taken to indicate, knowing the other irons used, a certain approximate physical structure and maybe some idea of the analysis. Where similar irons are used, and the resultant total carbon, manganese, sulphur and phosphorus in the metal is fairly constant, Table III, which can only be approximate, will be found useful in the endeavour to obtain a close structure on high-grade dry-sand castings.

Table III.—*Silicon Content, Section and Chill Test.*

	Si. content.	Minimum section of castings in in.	Maximum chill test in in.
1 ..	1.5	½	¼
2 ..	1.3	⅝	½
3 ..	1.15	1½	¾
4 ..	1.00	2½	1
5 ..	0.80	4	1¼
6 ..	0.60	6	1½

In conclusion, it is emphasised that it has not been the author's intention to discuss the manufacture of chilled rolls, but to emphasise certain essential principles of chilling and densening, at the same time indicating the degree of control necessary for success.

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Making Sound Castings

The Paper on "Cupola Practice and Carbon Control," which Mr. W. H. Bamford presented to the Birmingham Branch of the Institute of British Foundrymen,* stimulated the following discussion.

Mr. A. J. Shore asked whether, in the case of iron with controlled total carbon, it was still necessary to use chills.

Mr. G. R. Shotton, referring to Mr. Bamford's statement that there was little or no carbon pick-up in the well of the cupola, said he should have expected that there would be some. A high casting temperature was being used and his (Mr. Shotton's) experience of open-hearth melting was that total carbon was definitely increased, always dependent upon the temperature of the metal. The hotter the metal, the greater the pick-up.

Mr. J. Hird said he understood Mr. Bamford to say that porosity was aggravated by casting too hot. Did Mr. Bamford advocate keeping the iron in the ladle until it had cooled?

Mr. A. E. Lester asked for an explanation of how Mr. Bamford maintained the coke bed at the same height.

Efficacy of Keep's Test

Mr. T. R. Twigger, alluding to Keep's shrinkage test, said he gathered from Mr. Bamford that it had been found of considerable use in control. Personally, he had not seen much evidence to support the value of the shrinkage measurement. When installing an oil furnace, they particularly desired to have some ready means of control, and Keep's test was one of the first things that came into their minds. They found, however, that the variations in the actual amounts of shrinkage were exceedingly small. He would like to know if any particular care had to be taken in controlling the conditions under which the Keep's bars were cast, and whether Mr. Bamford considered the fracture was more important than the actual shrinkage. Had Mr. Bamford any experience of the use of soda ash in the cupola, in relation to carbon? In his own case, they had made some tests with soda ash and found that there was a tendency to lower total carbon when soda ash was used. Was that in any way akin to coating the coke with lime?

Hints on Cupola Control

Mr. L. W. Bolton (hon. secretary of the Branch) said he was interested to hear that Mr. Bamford used a comparatively low blast pressure on the cupola. He called it a "soft-blast cupola." For some years the British Cast Iron Research Association had been advocating the use of low-blast pressures, especially where steel was being melted. Mr. Bamford insisted on a thoroughly well-heated bed before charging commenced. Providing a bed with the whole of the coke red hot before charging took them half the way in good cupola practice. He was not surprised to hear Mr. Bamford say that he was using small metal charges of 500 lbs. In normal working, where they were melting pig-iron and scrap of fairly similar composition, there would be greater coke economy with a heavier charge. But where they were melting such widely dissimilar constituents as steel and 3 per cent. silicon pig, small charges helped in maintaining a uniform supply of metal of the same composition. Mr. Bamford had mentioned that all the coke used in the charges was carefully weighed. He (Mr. Bolton) agreed that when they were using dense coke at one time and a fairly-open grain soft coke at another, weighing was necessary. He would like to know if Mr. Bamford took into account the possibility of coke being wet one day and dry another.

Carbon Pick-up

Mr. W. J. Molineux, referring to the carbon pick-up after the melting of the charges, said he thought Mr. Field had proved fairly conclusively that, even with a low-carbon iron, the carbon pick-up after the metal got into the well was almost negligible. Mr. Field, he thought, took samples of metal as it trickled past the tuyeres and compared it with the metal tapped from the cupola. It seemed reasonable to suppose that the carbon was picked up as the metal trickled through the incandescent coke in the melting zone. It was very difficult to introduce carbon into a bath of metal. Regarding casting temperature, he thought that, on the whole, what Mr. Bamford had said was perfectly sound. Had Mr. Bamford any experience of temperatures above the range he had named, say, 1,650 deg. C.? He (Mr. Molineux) had found that it was quite possible to get opposite effects with these high temperatures.

Mr. J. W. Gardom said Mr. Bamford had mentioned that he had taken samples of steel from just above the bed and found that there was a certain amount of skin penetration of the carbon. He would be interested to know how Mr. Bamford got hold of the sample just above the bed.

Mr. Hunter inquired why 2.2 silicon was used instead of standard silicon iron.

Refined Iron Charges

Mr. H. G. Hall suggested that low-silicon iron was greedy for carbon, and took it up readily. Some years ago, he said, he was connected with a cylinder foundry, and he could confirm Mr. Bamford's remarks on the subject of small charges in the cupola where they wanted to produce high-class cylinders. They were using, at the time, a refined-iron charge with a small steel addition, and, if anything, their carbon results were more uniform than Mr. Bamford's, possibly due to the fact that they were using a more uniform charge.

Mr. E. W. Wynn said his experience definitely was that it was difficult to put carbon into molten cast iron. He thought the steel must pick up some of the carbon before it melted. In his opinion, the testing of their cupola working by fracture was rather difficult. He imagined that the amount of graphitisation was dependent not only on the carbon and silicon content, but also on the type of metal which they were charging into the cupola.

Shrinkage and Chill Depth

Mr. W. G. Morgan said his firm applied Keep's test, and their results were somewhat different from those of Mr. Bamford. Their silicon was about 1.9, with a total carbon of about 3.3. The shrinkage was 0.15 or 0.16. The chill came down to $\frac{1}{4}$ in. and the combined carbon went to 0.65 or 0.68 per cent.

Author's Reply

Replying to the questions, Mr. Bamford said Mr. Blythe had suggested that a 500-lb. charge was rather low, and wanted to know how synchronisation was obtained. In his (Mr. Bamford's) opinion, it really paid to reduce the charge and increase the capacity of the well in order to obtain better mixing. By so doing they obtained a thoroughly good mixture, and at the same time there were always five or six charges melted before they tapped out. They could adjust the blast to suit any degree of melting, while the carbon pick-up showed no difference, unless, of course, they had a high bed, when they would expect a high pick-up. As to the removal of chills from the castings, his reply was that they almost invariably removed them. With regard to Mr. Shotton's comment on carbon pick-up in the well of the cupola, he could only say that they had not experienced it. Samples of iron had been left in the well of the cupola for about two hours and, when they had tapped out, it had never been any higher in carbon than it was just before shutting down the blast, even when the iron had been really hot—1,400 or 1,500 deg. C.

Soundness and Time Factor

On the subject of porosity, Mr. Hird had asked if they held the metal in the ladle before casting in order to get sounder iron. His answer was that they did in the case of a small, thick casting, but on crankcase jobs, which were fairly thin, they poured straight away. Mr. Lester had inquired how they maintained the height of the bed during the run. If the bed began to drop it was indicated by additional sparking of the metal when tapped. Further, chill was immediately increased in the bar. Mr. Twigger had referred to Keep's test and asked if it was found that the fracture was more important than the shrinkage. In the case of a large casting, the shrinkage would be the principal feature, but with a small casting of about 1 ft. it did not matter. A fracture was the quickest guide. On the matter of soda ash in relation to total carbon, judging by appearances through the tuyeres it did not seem that the coke was covered by the soda ash. In their own case they had added soda ash to the charges for the last six months and found there was no difference.

In reply to Mr. Bolton, Mr. Bamford said there was such a thing as analysing coke for the water content. This was done twice a day in wet weather, and adjustments were made accordingly. To Mr. Gardom, who inquired how the sample of steel was obtained just as it entered the bed, his reply was that in the case in question the bottom was dropped just before melting finished and the steel recovered. Mr. Hunter had asked why they used 2.2 silicon instead of standard silicon iron. His reply was that if they got down to 1.7 or 1.8, probably, with dry sand moulds, they would have white castings. Mr. Hall was of opinion that low silicon increased the carbon pick-up. His own (Mr. Bamford's) view was that the pick-up was due to a high bed more than to anything else. They must keep the level of the coke-bed constant, whatever carbon was being used. His reply to Mr. Morgan's criticism was that they had always found a chill in the region of $\frac{3}{4}$ in. corresponded with shrinkage of about 0.16 in.

* Foundry Trade Journal, March 7, 1935, page 169.

American Committee on Methods of Metallographic Testing

At the meeting of the American Society for Testing Materials Committee on Selection and Preparation of Samples for Metallographic Testing, held in Philadelphia, the revised methods for preparing and examining specimens were carefully considered. The Committee intends that these methods will replace obsolete ones now in existence, since they are designed to present in convenient and condensed form procedures successfully used for both ferrous and non-ferrous metals and alloys. The Committee took action to recommend the publication as tentative of the methods. The first section of the proposed standard covers selecting, mounting and cleaning of samples. This is followed by discussion of recommended procedures for examination of various metals and their alloys, including aluminium, copper, iron and steel, lead, magnesium, nickel, precious metals, tin, zinc, and finally recommendations covering microscopy and photography. An extensive bibliography covering important articles and references to the subject of metallographic testing is included as an appendix to the methods. In the sections covering the various alloys the preparation of specimens is described, tables of etching solutions involving the reagent composition, method of use and application are given, followed by discussion of examination and identification of constituents. The Committee has expended a great deal of effort and time in the preparation of these methods, and when published they will be a ready reference for metallurgical laboratories. Mr. E. H. Dix, Jun., chief metallurgist of the Aluminum Research Laboratories, Aluminum Company of America, has been appointed chairman of Sub-committee I on Selection and Preparation of Samples, Committee E-4 on Metallography.

Essentials in the Production of Sound Steel Castings

By J. S. BENNETT, B.Met.

During the past decade a very great amount of attention has been paid to the mechanisation of the foundry and to various other improvements in foundry practice which tend to bring about an increase of productive efficiency in the foundry trade. A great number of these aids to production have been put into operation, with the result that the modern foundry is in a far better position as regards turning out good, sound work on an economic basis than the foundry of ten years ago. However, most of the improvements which have been made apply almost entirely to the business management of the trade. Processes have been speeded up by mechanical aid, mass production has come to the fore, handling and transport within the works have been mechanised, while, in the main, the science of producing the actual casting remains unexplored. It is possibly due to the interest centred around these incidental improvements that a very conservative view is being taken of the development of the fundamental science on which founding is based.

Actually, one finds that in many of the smaller steel foundries of the country, very little can be done in the way of installing modern equipment, except where specialisation is possible. The price of many mechanical devices is so high as to be prohibitive unless the machine is to be in constant use. Thus, in the jobbing foundry, apart from pneumatic rammers and such small items, the foundry is run on the same lines as it was twenty or thirty years ago.

Now during these years much work has been done with a view to improving the actual science of founding. Much more still remains to be done, but it behoves every foundryman (the jobbing foundryman in particular) to avail himself of the results of these investigations which have been made during the past few years.

Sands in the Ordinary Foundry

A great deal of research on the control and conditioning of foundry sands has been carried out recently. Actually, in the small foundry it is very difficult to make laboratory tests of the properties of the various sands employed; in such cases the feel of the sand may be more useful than any empirical figures from the laboratory. Most foundries will have on their hands a number of sands. Usually:—(1) Moulders' composition; (2) a yellow moulding sand; (3) a green-sand mixture; (4) an oil-bonded core sand; and (5) black sand. The question is: can these mixtures be improved economically, and, if so, how?

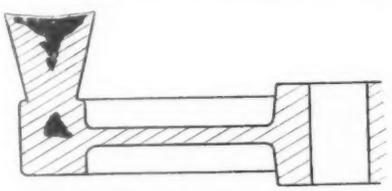

Fig. 2.—Design of Riser to Facilitate Feeding.

Moulders' composition can be dismissed summarily. It is still desirable in large moulds which have to stand a great pressure from a head of molten metal in addition to the associated high temperatures. In other cases it can be replaced by a yellow sand.

A natural yellow moulding sand is usually milled with the required quantity of silver sand to regulate the bond. It is often an advantage to add a small quantity of linseed-base core oil, which, giving added dry strength, will save any tendency to "scab." This may also allow the addition of slightly more silver sand, giving a more refractory and slightly cheaper mixture. The number of green-sand mixtures in use is so great that any discussion of their merits is out of the question here. Probably every foundry has its own favourite mixture which has been found suitable.

Oil-bonded core sands are possibly the most simple mixtures used, but as the whole strength of the material depends on the drying, this should, whenever possible, be under pyrometric control. Few founders realise that, by preparing their own core oil from linseed oil with admixtures of various gums and/or tar, a pecuniary saving can be effected with no loss of efficiency, but accompanied by the removal from the core-shop of a very pungent smell which is characteristic of certain proprietary oils!

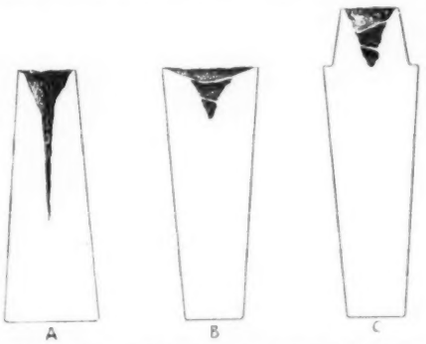

Fig. 1.—Development of Ingot Moulds with the Object of Minimising Discard through Piping.

The condition of black sand is at least as important as any of the facing sands. American foundries have found it advantageous to recondition black sand by the removal of all "dusty" particles below a certain mesh, thus giving a highly-porous sand which cuts out any need for spike venting of moulds (which is never efficient) and is entirely dispensed with except from core-prints.

Methods of Feeding

Having assembled his raw materials, the foundryman must decide, firstly, where and how to "run" his castings and how to "feed" them. In other words, he must completely fill his mould with molten metal and arrange for a surplus supply of metal in the form of risers which will supply molten metal as the cooling casting below contracts.

Much can be learnt, even at this stage of development of the industry, from the study of ingots. The old method of casting ingots, narrow end up, led to the formation of a long "pipe," which became much shorter and wider if the ingot were cast wide end up. An observation of these facts led to another improvement, *i.e.*, the placing of a feeder "head" in the shape of a truncated ingot mould of the *old* type on top of the actual mould. Thus we have a "head" designed to feed as deeply as possible, above a mould which cools with a short, wide pipe. The shrinkage cavities of the three types are compared on Fig. 1.

Not only was this true when the ingot was cast in a cast-iron mould, but sand-cast ingots showed the same characteristics (as shown by A. Kriz and others). Therefore one would expect that this knowledge would be applied to the feeding of castings in the foundry. However, it seems that the foundryman has stuck to the design of feeder head which was deemed most suitable in the dark ages when as much weight as was reasonably possible was put into risers, which had to be so designed that they could be knocked off with a striking hammer, instead of being burned off by oxy-acetylene, as in modern practice. The design of risers, therefore, became standardised as shown in Fig. 2—a riser designed to freeze first at the lower end, leaving a misleading pool of molten metal above, which could not feed into any actual or potential cavity in the casting. If, however, the design of the riser is changed to that shown in Fig. 3 (it may sometimes even be advisable to increase the width of the mould at the junction with the riser "AA," the extra metal being ground off in fettling), we have, in effect, a long-pipe ingot above the casting, in other words, a head of metal which will feed to the last drop and which allows any cavity which may form in the actual casting, to be filled by "topping up" the risers.

Much work has been done on the study of the solidification of steel ingots, by firstly studying the solidification of wax under similar conditions. Commercial stearic acid, having a melting point of 50 to 55 deg. C., when cast from a temperature of 60 deg. C., gives the characteristics of solidifying steel in a slightly exaggerated manner. The effect of this "inverted" type of riser was firstly studied in the feeding of wax castings. A small blank spur wheel was chosen for simplicity, being cast with a riser on the boss and four risers, equally spaced around the rim. The mould was fed through a "horn" runner, so that the metal entered the rim, from below, at a point mid-way between two of the risers. Some trouble was experienced from air trapped in the mould, forming what, at first, seemed to be large shrinkage cavities in the boss and rim of the blank. However, by more rapid casting, keeping the runner full, this was overcome, and the inverted type of riser invariably gave a sounder casting, although the percentage of "metal" in the form of risers were appreciably less. Figs. 2 and 3 show the average type of shrinkage cavities formed.

The procedure which gave the most sound castings was to pour rapidly from the first drop without any pause until the wax was just in the risers, so that the runner was always full and no air could be sucked in. The risers were then filled by pouring a quantity of wax into each, thus ensuring that the hottest "metal" would be present for feeding. This type of inverted riser has since been tried out in a steelfoundry and, up to the time of writing, has shown very good results.

As far as the production of molten metal is concerned, the steelfounder is in a far better position than the ironfounder, for the metal is more directly under his control, and, whether open-hearth, electric, pneumatic, or crucible furnaces are employed, no foundry should have any difficulty in producing metal which, in a properly-annealed or normalised state, will give a test well above that required by the various specifications. If the analysis be correct, there is never any need to use expensive alloys for cleaning and/or deoxidising the metal. Even from the Bessemer, the metal can be efficiently

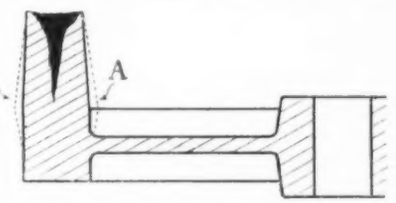

Fig. 3.—Design of Riser altered to Minimise Piping.

(*Concluded on page* 256.)

XUM

The Mechanics of Porosity in Steel Castings*

By R. C. WOODWARD,† Milwaukee, Wis., U.S.A.

Porosity in steel castings is as old as the art itself, and has inspired a volume of literature. The defective condition has been materially lessened by the use of aluminium in the metal and by sand control. In the remedial processes there have developed two opposing opinions as to cause and cure. Most metallurgists and melters unite in condemning the sand, while moulding foremen and sand supervisors generally are convinced that the trouble lies mainly in the metal. The exponents of each theory are so strongly convinced that when the opposing opinions clash, there is usually generated more heat than light; with the net result that improvement has been slow and that porosity has continued to be an expensive evil to the industry.

This Paper deals with that type of porosity which is seen just under the surface of castings, often called "pinhole" porosity. While much has been written on the subject, comparatively little has been said as to just how any alleged cause produces the effect. It is attempted here to show the mechanics by which, under a set of conditions that often exists in steel foundries, porosity may be set up. It is felt that a more effective approach to the whole problem will be possible if there is a clearer understanding of the manner in which generally-recognised causes produce their effect.

In a certain steel foundry where porosity had been perhaps more persistent than is usually experienced, a study of rejection records was made covering a period of six years, 1927 to 1932 inclusive. A total of 21,057 castings rejected on account of porosity, was considered. It is sometimes assumed that porosity is an affliction of very small castings only. The average weight of these castings was 24.22 lbs., and of the total weight involved, 54.38 per cent. had to do with pieces weighing 50 lbs. or more each. The melting units were acid open-hearth furnaces, and the castings produced ranged in weight from less than a pound to 25 tons each.

Rejected Castings Studied

It was generally believed that porosity occurred in cycles which seemed to be seasonal, rejections being heavier in summer than in winter. To determine how true this might be, tabulations were made by months and by quarters. It was interesting, and sometimes significant, to note how persistently porosity would at times follow a single pattern, or the output of certain workmen, or the output of certain sections of the foundry.

While the records were being considered, the microscope showed that some specimens having excessive porosity had also excessive non-metallic impurities in close proximity to the pinholes. By etching with various reagents, these non-metallics were shown to be silicious, with some ferric iron, and probably with some alkalies and alkaline earths in small amounts. No ferrous iron was shown, indicating that they had no connection with the main body of slag.

Speculating as to what relation, if any, these inclusions might have to the offensive pinholes, it was assumed that excessive inclusions throughout a cross-section would probably mean excessive inclusions on the surface also; and special thought was given to the ones imbedded in the surface.

When molten metal enters the cavity of a green-sand mould, considerable pressure is set up by the volatile mould substances, this pressure being equal in all directions. In the freezing cycle of a green-sand casting a skin envelope is formed very quickly. Before the envelope is formed, there probably is sufficient ferrostatic pressure to prevent the above-mentioned gases entering the casting. As the envelope forms, the interior metal rapidly loses viscosity and ferrostatic pressure. The gas pressure continues to act against the envelope, which solidifies at approximately 1,370 deg. C. However, the surface inclusions, having a considerably lower freezing point than the envelope, continue to be liquid while they are subjected to this same pressure. The freezing point of the inclusions will vary with their composition, and could easily be 535 deg. C. less than their supporting steel envelope.

Therefore, there must come an instant in the freezing cycle of a casting when the envelope is solid, the surface inclusions liquid, with mould gases acting against the entire surface, and the interior ferrostatic pressure practically nil. With such a combination of circumstances existing, a minute amount of mould gas could enter the cast *through* the inclusion. It would meet a much higher temperature and be forced to expand. Perhaps some of it would be ejected from the casting, but a cavity would be formed in the casting just under the skin where the metal would still be plastic, and the damage would be done.

It is generally said that porosity exists just under the skin of castings; and when some of this skin is removed by annealing or machining, the hidden pinholes are exposed. If the theory advanced here be true, these cavities extend to the surface, but through inclusions which are themselves too small to be noted by unaided eyesight.

It was felt that, if the theory had a basis of fact, sufficient searching should find pinholes with the non-metallic matter in place, pierced by the hole through which the gas entered. They are not hard to find. Fairly large ones may be noted in visual examination, although the slag is very brittle. Sand-blasting and other cleaning operations generally remove it. Fig. 1 shows a reproduction of a photomicrograph of a specimen taken at a magnification of 50 diameters, showing the ring of slag in the neck of porous cavity.

Returning to consideration of the tabulated data, the assumption of seasonal porosity is in some degree substantiated. Possible factors which might cause it were sought; and by a process of elimination the materials used for binders were most suspected. If surface inclusions induced porosity, a concentration of slag-forming particles on the mould surfaces should show its effect on the casting. Two experimental moulds were made from the same pattern, and one was liberally sprayed with a 10 per cent. solution of sodium hydrate. This mould, which was not dried after being sprayed, produced a very porous casting, and the other mould produced a sound one. This experiment was repeated a number of times, but while the expected porous result was generally yielded, it varied widely in degree.

Admittedly the opinion suggested here is just an individual one as to one cause of porosity. It may be wrong. It is advanced with the hope that it may be of some help to the industry at large in overcoming a defect in the product which is at times serious. It needs further investigation beyond the scope of the writer's limitations. If it stimulates such investigation and discussion, its presentation here will have been felt justified. If it points the way to any improvement in steel castings by emphasising the need for both clean metal and clean sand, with properly-regulated mould permeability, the Paper will have served a useful purpose and contributed in a small way to the good of the cause.

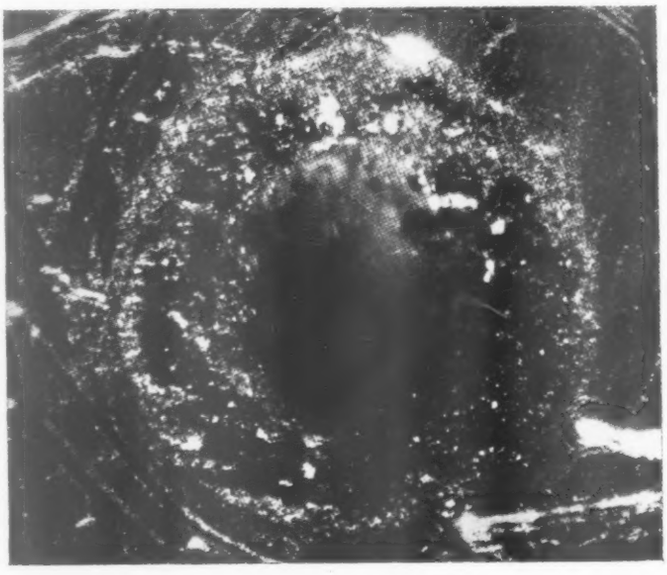

Fig. 1.—Photomicrograph showing Ring of Slag in Neck of Porous Cavity. × 50.

* Abstract of a Paper presented at the Annual Meeting of the American Foundrymen's Association.

† Supt., Geo. H. Smith Steel Castings Company.

The Vanadium Problem in the Urals

In "Redk. Met." M. N. Sobolievdiscusses the vanadium ores in the Urals which are titanomagnetites containing less than 0.5 per cent. of vanadium and from whose non-magnetic concentrate a pig-iron is produced containing 0.5 to 1 per cent. of vanadium. This pig-iron when blown in a Bessemer converter yields up 90 per cent. of the vanadium to the slag which is found to contain 3 to 5 per cent. V and 60 per cent. Si. The crushed slag is roasted for 3 hrs. with 10 per cent. sodium chloride at 750 to 800 deg., after which 90 per cent. of the vanadium can be dissolved in water as sodium vanadate. The solution contains no iron, chromium or manganese, the overall recovery of this process being 65 to 75 per cent.

Theory and Practice in Aluminium Founding

RESEARCH NARROWING GULF

Dr. Slater's Paper,* read before the London Branch of the Institute of British Foundrymen, over which Mr. A. G. Beech presided and which was printed in recent issues of the Foundry Trade Journal, formed the basis of an interesting discussion on the possibilities of making aluminium castings free from pinholes and other defects. The discussion was opened by the Branch-President, who congratulated Dr. Slater upon the manner in which he had covered the subject, and asked if the author could suggest any aluminium alloy which would stand up to continual heavy pressure and would not fail within a comparatively short time by fatigue. During the last two or three years he had had considerable experience of the use of aluminium for making moulding boxes; a large number of aluminium alloys had been tried, and they had been cast in various ways, but all of them, after having served very well indeed for a short time, had suddenly collapsed. Sometimes the outside frames of the boxes, and sometimes the bars in the boxes, would give way, and he had come to the conclusion that for moulding boxes, which were subjected to continual heavy pressure, aluminium was a failure.

Aluminium Moulding Boxes

Dr. Slater, before replying to the Branch-President, first acknowledged the help he had received from his colleagues on the staff of the British Non-Ferrous Metals Research Association.

An alloy to be used for making moulding boxes needed to be resistant to both fatigue and shock; one should therefore choose an alloy having a high fatigue range and a fair amount of ductility. Some assistance in making a choice could be obtained from a number of publications which were available, listing the properties of the various alloys. Among the more reputable of these alloys the Branch-President might be able to find something more suitable than the alloys he had used for moulding boxes. Dr. Slater had in mind a publication by the American Society for Testing Materials,[1] dealing with the service characteristics of the light metals and their alloys; it contained tabulated data on such matters as the Branch-President had mentioned. It was difficult to specify an exact composition, for there were so many from which to choose, but possibly one of the heat-treated Silumin alloys might be useful for making moulding boxes; they possessed a fairly high fatigue range, together with a fair degree of toughness. Again, alloys of the "Y"-alloy type, or modifications of them, might be suitable.

Casting under Pressure

Mr. J. F. Page (Birmingham Branch) said that the solidification of sand castings under pressure, which was an entirely new development, might be of great interest, but that quite obviously it involved some rather serious practical considerations. He asked if the investigations had proceeded far enough to enable Dr. Slater to give any advice as to how casting under pressure could be carried out under practical foundry conditions.

Dr. Slater was unable to answer the question completely. However, Prof. Hanson and himself had used a single autoclave when making their experiments. That would be quite uneconomical for the average run of commercial castings, but there were possibilities in regard to the special castings, such as very large pistons, and the like, where, even if only slightly improved properties could be secured, they were worth aiming at. In such cases there might be some grounds for using a single autoclave or a boiler shell, or the like, which an engineer could easily design for the purpose.

Making Remelt Metal Sound

Mr. A. F. Gibbs (Past Branch-President) asked if Dr. Slater had had experience of the use of aluminium scrap derived from castings which had been poured into green-sand moulds, bearing in mind that a certain amount of moisture would be picked up from the sand; and whether he would recommend the use of any specific quantity of scrap per charge.

Dr. Slater said it was difficult to answer Mr. Gibbs' question, because the quality of the scrap would depend, first, on the quality of the original melt, and, secondly, on how much it had deteriorated in the green-sand mould due to the moisture therein. As to the quantity of scrap which one might add to new metal, without spoiling the new metal too much, he said the ideal, of course, was to use no scrap at all, if one wished to produce sound castings without any treatment of the melt. In practice one could not do that, and the foundryman was forced to adopt some method for de-gassing his metal, if he wanted it perfectly sound, and if his melting methods were such that there was deterioration in the course of the melting. Here lies the real practical difficulty, but some of the suggestions which had been made with regard to de-gassing processes should be of assistance.

The Archbutt Process

Mr. Chas. Cleaver, commenting on an illustration shown by Dr. Slater of metal which, having been melted and remelted quickly, was in consequence perfectly sound and de-gassed, which appeared to him (Mr. Cleaver) to be the most practical of the various methods expounded, said he noted it was not in favour on account of time and cost of remelting. Was the stirring-in of flux satisfactory?

Dr. Slater replied that all the methods he had referred to had some degree of efficiency, and he had attempted to make a brief comparison of them. Certainly some fluxes would improve very bad metal and render it only moderately bad; others still might be more efficacious.

Mr. Cleaver said he had in mind starting with reasonably good metal.

Dr. Slater said that some of the methods would make moderate metal perfectly good metal, provided certain conditions were applied. He had not yet observed any authoritative statements concerning the relative efficiency of the various fluxes, but it was known that some were better than others, and some might be quite adequate for Mr. Cleaver's purposes.

Use of Proprietary Fluxes

Mr. G. C. Pierce (Past-Branch-President) said it would be realised that there was yet no panacea for pinholes in aluminium alloys. It was very nice to visualise the pumping of gases into pots of metal in the laboratory, but when one was producing castings of all shapes and varieties, in probably dozens of alloys, on a competitive basis, it was an impracticable suggestion. He had experimented with the Archbutt process, but there again difficulties were encountered by reason of the time factor, and he still asserted that the Archbutt process was not entirely a panacea for pinholing in aluminium; undoubtedly, it was helpful, but it was a mistake to assume that it would dispose entirely of pinholes in aluminium.

Commenting on the use of fluxes in the metal, he said that all who were conducting aluminium foundries were bothered from time to time by people selling materials which would eliminate pinholes from aluminium; and they would be foolish indeed if they did not try some of these things sometimes. He had a perfectly open mind on the matter, and believed that those who were trying to perfect the method of immersing a chemical in the metal, much in the same way as in modifying some of the alloys, were likely to be on the right lines.

Dr. Slater endeavoured to give Mr. Pierce a little more hope concerning the possibilities of eliminating pinholes from aluminium. He had been particularly interested in this particular aspect of aluminium founding during the last few years, on behalf of the Research Association. He and his colleagues had proceeded, or at least were attempting to proceed, a few steps beyond the point indicated in the Paper, and probably they would have something further to report in due course.

Increased Shrinkage follows Pinhole Removal

Mr. J. Laing, bearing in mind Dr. Slater's comments on the advantage of completely de-gassing aluminium for die-casting processes, asked if he could say with confidence that the complete de-gassing of aluminium alloys would not increase the solidification shrinkage troubles in sand castings.

Dr. Slater replied that when a metal was de-gassed, the volume which was occupied previously by pinholes—that volume was 2 or 3 per cent. in moderately-bad metal when sand-cast—was replaced by shrinkage. So that, irrespective of the method of casting, whether chill or sand, if the pinholes were removed it was necessary to compensate for the additional shrinkage that would occur; the average foundryman knew quite well how to tackle this matter.

Hydrogen Inclusion

Mr. Freeman Horn (British Aluminium Company), commenting on Dr. Slater's theory that metal stored under bad conditions absorbed hydrogen, asked if it were really correct to say that the result of atmospheric corrosion on aluminium was the absorption of hydrogen. He had thought it was recognised that the cause of the atmospheric corrosion of aluminium was its combination with the oxygen in the air in the presence of moisture, just as in the case of iron. However, assuming a certain amount of hydrogen was absorbed, he asked why Dr. Slater had stated that when the metal was re-melted and again solidified the hydrogen was released. If solid metal could absorb hydrogen, surely it was capable of keeping it when again solidified!

With regard to the point that the product of the corrosion was hydroxide, and that, when metal having a certain amount of that hydroxide on the surface was melted, the hydroxide became calcined, and gave up its moisture of combination, so that the hydrogen and the moisture went into the metal, Mr. Freeman Horn said that the hydroxide of aluminium was in the form of a very fine white powder, which was brushed off very easily; if the average person took an ingot out of storage and saw some of this white powder on it, he would brush it off, or at least would brush most of it off, so that the amount left adhering to the surface would be very small, and the amount of hydrogen contained in the hydrate part of it was almost negligible. Quite apart from that, one could not fully calcine hydroxide at anything like the temperature of molten aluminium; it required very much more than a temperature of 800 deg. fully to

* Foundry Trade Journal, March 21, 1935, page 201.

1 "Service Characteristics of the Light Metals and their Alloys." Report prepared by a sub-committee of the American Society for Testing Materials. See "Proc. A.S.T.M.," 1934, Vol. 34, Part I.

calcine hydroxide of aluminium, except by a very long period of calcination.

Dr. Slater said the assumptions made with regard to the causes of hydrogen sorption were based on experimental data. There was some dispute as to whether hydrogen could be absorbed by the solid metal whilst it was undergoing corrosion. The usual method of atmospheric corrosion with aluminium was electrolytic, in which small cathodic areas were formed, and hydrogen in the nascent form was evolved as corrosion proceeded. It had been shown by two or three investigators[2] that nascent hydrogen could penetrate through solid aluminium, and he assumed that that hydrogen was retained in some form in the metal. It was possible that the hydrogen accumulated in cavities inside the metal, just as when steel was pickled, the nascent hydrogen evolved would penetrate the metal and accumulate in local areas, such as at cavities and non-metallic inclusions, to form blisters. It was possible that the hydrogen could remain in the cavities until the metal was melted.

With regard to the decomposition of aluminium hydroxide on heating, he said it was decomposed over a temperature range up to 1,400 deg. C. During the course of heating, a certain portion of the products of its decomposition would come into contact with the liquid metal. As to the amount of the corrosion product, he said it required very little aluminium hydroxide to give a sufficient quantity of gas, in cubic centimetres, to gas up the melt; thus 1 gramme of $Al(OH)_3$ on decomposition will give over 200 c.c. of hydrogen. He disagreed with the suggestion that the corrosion product could be brushed off by hand; it was a little more adherent than that, and in his experience of cleaning ingots he had found it necessary to abrade the surfaces of the metal by filing. Even scratch brushing did not suffice.

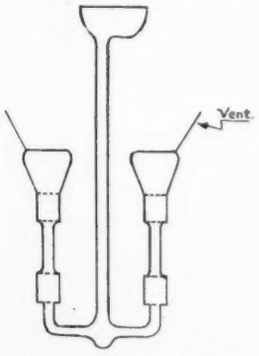

Fig. A.—Type of Test-Piece suggested for Light Alloy Work.

Vote of Thanks

Mr. A. F. Gibbs (Past-Branch-President) proposed a vote of thanks to Dr. Slater for the wealth of both practical and theoretical information he had given, and expressed thanks also to the British Non-Ferrous Metals Research Association for the research work it was doing. Such work would do a great deal to help the foundrymen to overcome their troubles.

Mr. H. O. Slater (Past-Branch-President), who seconded, said that, as one concerned with the practical work, he had enjoyed the Paper and appreciated very much Dr. Slater's treatment of the scientific aspect.

After commenting that aluminium was a difficult metal to deal with, Mr. Slater mentioned his experience in casting an 8 per cent. aluminium-copper alloy in an iron chill. The temperature of the iron chill, of course, was of great importance, as was also the dressing. He had at first tackled the problem by heating the mould to the ordinary temperature for non-ferrous work, *i.e.*, about 80 deg. C., and had used a wet dressing of lard, oil and plumbago. To his astonishment, when the billet was turned out, it had almost separated, appearing as separate castings joined together in places. Subsequently he had heated the mould to 130 deg., and had used a dry dressing, a gas flame being applied, and thereby had achieved success. There was only 5 per cent. deadhead on the billet, and on being heated to 800 deg. it had rolled perfectly.

Commenting on Dr. Slater's use of compressed air for applying pressure to moulds, he said that for a number of years practical foundrymen had applied pressure under special circumstances by using a deep cup, filling it with sand after pouring, and placing on top a 56-lb. or any other suitable weight.

Mr. Slater described a method of pouring aluminium test-bars, by means of which he had increased the tensile strength of the bars from 7 to 12.5 tons. He had taken the view that aluminium was very similar to malleable iron, steel, cast iron and other metals, in that the application of pressure was of great value. But if one cast with an open head and adopted pressure, some pressure would be lost through the head. After experimenting, he had increased the fillet at the neck of the test-bar. Two test-bars were cast in a box, and he had run the metal in at the bottom, the method of applying the pressure being to put 1 ft. of height on the runner. The head at the top of the castings was enclosed, except for a small vent hole.

Dr. Slater, responding to the vote of thanks, which was accorded with enthusiasm, assured the meeting that he appreciated the opportunity of reading the Paper before the Institute, and had enjoyed the experience.

[2] D. Alekslev and L. Sabinina. "J. Russian Phys.-Chem. Society," 1924, Part 56 (Physics), page 560.

Essentials in the Production of Sound Steel Castings

(*Concluded from page 253.*)

deoxidised by the usual ferro-silicon and ferro-manganese additions to the bath, with perhaps a small addition of aluminium to the stream of molten metal as the ladle is being filled.

Pyrometric control of casting temperatures is rarely of any real advantage. There are so many variable factors, other than the temperature of the metal, which affect the fluidity that, to an experienced eye, the appearance of the metal is a more accurate guide.

Unrestricted Contraction

Having the molten metal in the ladle, the pouring method previously laid down as the most successful in the case of wax casting is usually found to be equally so in actual foundry practice. The author has in mind the case of a very simple casting, weighing roughly 1½ cwts., which, being of good outside appearance after fettling, was selected for a special test. After being specially heat-treated, it was tested to destruction, and was found to be little more than a mere shell, due to air carried into the mould by slow pouring. A ladle-nozzle defect had caused this divergence from the usual practice, and it was found afterwards that a number of castings from that heat showed the same defect, although castings from the same batch, cast according to the normal practice from another heat, were quite sound.

In addition to the tendency of a slow stream of metal to draw air into the mould, there is an additional danger of the formation of droplets of metal which, being oxidised, do not become welded into the mass of metal again, but find their way into the most awkward corners, from the point of view of the electric welder. In the case of a casting where rapid filling of the mould seems likely to endanger some parts of the mould itself, a few rows of springs or horse-shoe nails will usually stem the flow of the metal sufficiently.

As soon as possible after casting, the moulds should be knocked out and the castings allowed to cool and contract freely in a place free from drafts. Contraction is the jobbing foundryman's greatest bugbear, the reason being that very rarely do two jobs contract under the same conditions. Even when it is impossible to knock a job out for some time after casting, it should always be efficiently eased. Even the most intricately-cored castings of the bedplate type will give little trouble if they are well bracketed and eased at the earliest possible moment.

Heat-Treatment

It is always essential that the process of annealing the castings should be efficiently supervised. It is very rarely that a test fails in the foundry from any other cause than under- or over-annealing (usually the former). It is hardly ever sufficient to trust a pyrometer chart unless this gives readings of at least two thermocouples situated in different parts of the annealing furnace. Actually, slightly better mechanical properties will result if the castings are "normalised" instead of being annealed. This means that the castings are heated to 900 deg. C., or thereabouts, and are soaked at that temperature for the usual number of hours, after which they are pulled out of the furnace and allowed to cool in still air. This will give a tensile strength of some 8 to 10 per cent. higher than the annealed metal, without lowering the elongation.

In conclusion, the author would like to point out that, whereas, even in the jobbing foundry, there is a certain specialisation of labour (each moulder will stick to the same type of pattern as far as possible), there seems to have been little effort made towards specialisation in the administrative staff. In the average small foundry it is common to find a number of the staff each doing, say, a quarter of four distinct jobs. Now, there is no place where specialisation pays as well as in the "brain" of the organisation. This seems to have been realised almost everywhere but in the foundry, and it seems that, as soon as there is specialised administration, there will be paid to the founding science the attention which that science deserves.

Catalogues Received

Pig-Iron. Messrs. Dorman, Long & Company, Limited, of Middlesbrough, have sent us an eight-page pamphlet which illustrates the fractures and details the composition of Cleveland, Clarence Special, B.S. hematite, basic, pig-irons, ferro-manganese and spiegeleisen. It is nicely presented, and the technical information it contains makes it well worth while procuring and filing for reference.

Bronze Castings. We are very pleased with the second edition of "Taurus Bronze Castings," just issued by Messrs. David Brown & Sons, Limited, of Huddersfield, because it is one of the very few which really does credit to the foundry industry. Its cover is particularly artistic, the letterpress well printed and intelligently written, the illustrations well chosen, clear and nicely set out, and the micrographs are such as will be appreciated by the metallurgist. They have not, as is so often the case, been prostituted by the advertising department. Unlike some non-ferrous foundries, the whole of the propaganda is set out to enhance the goodwill of the Taurus trade mark. This to our mind is wise, as the dilution emanating through a firm carrying ten or twenty trade marks must strain the imagination of the sales staff. Under their trade mark, twelve alloys are marketed under a number. As the telegram is still used as a means of communication, these "marks" assume some importance amongst those who still have some regard for the injunction "Ilka mickle maks a muckle"; we suggest that Mark I centrifugally cast should be Mark XIII. We congratulate the officers responsible for this publication.

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This Week's News in Brief

Trade Talk

H.R.H. the Prince of Wales will visit the British Industries Fair, Castle Bromwich, on Thursday, May 23.

We are officially informed that the Brussels International Foundry Congress will be held from September 20 to 25.

The North British Steel Foundry Male Voice Choir, Bathgate, held their annual concert in the Corn Exchange, Bathgate, on April 2.

Two electric cranes have been ordered from Messrs. Babcock & Wilcox, Limited, Renfrew, for a Lithuanian harbour, at a cost of over £10,000.

Edinburgh Town Council has accepted the tender of the Stanton Ironworks Company, Limited, Nottingham, for the supply of about 700 tons of cast-iron pipes of various sizes.

An order for the construction of two torpedo-boat destroyers for the Polish Government has been secured by Messrs. J. Samuel White & Company, Limited, of Cowes, Isle of Wight.

The Cunard-White Star liner "Mauretania" (30,696 tons), built by Messrs. Swan, Hunter & Wigham Richardson, Limited, at Wallsend in 1906, has been sold to Metal Industries, Limited, and is to be broken up at Rosyth.

A conference of gas managers and engineers is to be called at an early date to consider the proposal to establish a gas grid for Lanarkshire and Renfrewshire. For some time, it is stated, the Board of Trade experts have been working out the details of the scheme.

It has been learned officially that Messrs. Fleming & Ferguson, engineers and shipbuilders, have secured an order for a sea-going hopper dredger for the Admiralty service at Portsmouth. The dredger, which will be 168 ft. in length, will be of 600 tons measurement.

It is understood that an offer has been made by General Refractories, Limited, to shareholders of Messrs. J. Grayson Lowood & Company, Limited, manufacturers of silica and firebricks, etc., of Sheffield, to purchase the shares for cash or effect an exchange of shares.

The Wreath Quay Engineering Works of Messrs. MacColl & Pollock, Limited, at Sunderland, on the River Wear, have been sold to Thos. W. Ward, Limited, of Sheffield, and the extensive plant formerly used for marine engineering and boiler making is to be dismantled at once.

Plans for establishing a museum of old Sheffield tools and plant at a disused works at Beauchief have been furthered by the offer of the gift of the works to the city by the J. G. Graves Charitable Trust. The works contain an old tilt-hammer worked by a water-wheel, which is to be restored.

Mr. Francis J. Barraball, foundry and engineers' supplier, of 10, Okehampton Road, London, N.W.10, informs us that owing to increased business, he has found it necessary to acquire further accommodation. His new address is :—33, Rydal Gardens, South Kenton, Wembley, Middlesex. Telephone : ARNold 3044.

The Sturtevant Engineering Company, Limited, have recently received orders for electrostatic precipitators from the Leicester, Nottingham and Leeds Electricity Departments. A somewhat unusual departure has been made in the case of Nottingham, in that the precipitators will be built on the roof of the power station.

A blast furnace of modern type and equipment has been built by the Millom & Askam Hematite Iron Company, Limited, to replace furnaces of an older type, and will be in operation shortly. A further unit of the same type, also in replacement of older furnaces, is in course of erection. An ore-sintering plant is also in course of erection.

Operations have commenced at the new iron-foundry at Athy, County Kildare, the switch which started the cupola blower being thrown in by Mrs. Hosie, wife of Captain H. J. Hosie, the managing director of Industrial Vehicles (Ireland), Limited, the firm promoting the new concern. The moulding shop, which has an iron framework with corrugated-iron exterior, and concrete floor, occupies an area of 15,000 sq. ft. Three tons of glass have been used in the windows of the structure. The cupola has a melting capacity of 6 tons per hr. The new concern, which will trade under the name of the I.V.Y. Foundry, will manufacture all classes of castings, including rain-water goods.

Messrs. Crossley Bros., Limited, of Openshaw, report that the demand for heavy-oil fuel engines is increasing steadily and engines are now in hand for use in many foreign countries, as well as at home. Among the recent contracts placed with Crossley Bros., Limited, are orders for further engines for the British Broadcasting Corporation. Two new engines are required for standby generator sets at the North Scottish and North-East England Broadcasting Stations. Each will be of the latest high-efficiency, 6-cylinder, 6-crank Crossley Vertical Diesel type, of 600 b.h.p., and will be similar to the Crossley sets already installed by the B.B.C. at Broadcasting House, London, and at the Scottish and the West Regional Stations. Engines built by Crossley Bros., Limited, and by their associated company, Crossley-Premier Engines, Limited (formerly The Premier Gas Engine Company, Limited, Nottingham), are in use and have proved their merits in every class of drive. They are to be found driving generators, pumps, compressors, etc., in every corner of the world.

Contracts Open

Egypt, April 17.—610 metres of 150 mm. dia. and 25 metres of 80 mm. dia. centrifugally cast pipes, special castings, etc., for the Ministry of the Interior. The Department of Overseas Trade. (Reference G.Y. 14,994.)

Richmond, April 26.—Supply and erection of one 4-in. horizontal centrifugal pump, with electric motor, for the Town Council. Mr. H. P. Williamson, water engineer and manager, Hotham House, Heron Court, Richmond, Surrey. (Fee £2 2s., returnable.)

Egypt, May 4.—2,600 metres of 150 mm. dia., 850 metres of 100 mm. dia., and 150 metres of 80 mm. dia. centrifugally cast pipes, with specials and fittings, for the Ministry of the Interior. The Department of Overseas Trade. (Reference G.Y. 14,993.)

Wantage, April 22.—For the Urban District Council :—Supplying and setting to work one well pump of the three-ram type and one horizontal crude-oil engine, capable of lifting 10,000 galls. of water per hr. The Waterworks Engineer, Grove Street, Wantage.

London, April 30.—The Bengal and North-Western Railway Company, Limited, invites tenders for six locomotive boilers and six pairs cylinders, etc. Mr. W. R. Izat, managing director, 237, Gresham House, Old Broad Street, London. (Fee 10s., non-returnable.)

Barnard Castle, April 23.—For the Urban District Council :—Providing, laying, jointing and testing about 1½ miles of 3-in., 6-in. and 7-in. cast- or spun-iron spigot and socket water mains, with specials and valves, etc. Messrs. Taylor & Wallin, 1, Saville Place, Newcastle-upon-Tyne. (Fee £3 deposit, returnable.)

Personal

Mr. John Harold, a well-known West of Scotland foreman, who has just completed 47 years' service with Messrs. L. Sterne & Company, Limited, refrigerating engineers, Crown Ironworks, Glasgow, was honoured by his colleagues on April 5 on the occasion of his retirement.

Mr. T. A. Crowe, assistant engineer manager with Messrs. R. & W. Hawthorn, Leslie & Company, Limited, Newcastle-upon-Tyne, has been appointed engineer manager of Messrs. John Brown & Company, Limited, Clydebank. The vacancy was caused by the promotion of Mr. Stephen Piggott to the position of resident director in charge of the Clydebank yard in place of Sir Thomas Bell, who has retired.

The Etna Iron & Steel Company, Limited, Motherwell, intimates that Mr. William Cunningham has resigned his position as managing director. He has been prominently associated with the company almost since its inception in 1889, and as he remains a director his long experience with the company and wide knowledge of the iron and steel trade generally will be available. Mr. James Kerr, the chairman, becomes also managing director.

The Foundry Trades' Exhibition

We are indebted to the Carborundum Company, of Trafford Park, Manchester, for pointing out to us that the list we published of exhibitors in the Foundry Section of the forthcoming exhibition at Olympia was somewhat misleading, as a number of firms like themselves, who have taken space in the Shipping, Engineering and Machinery division, would under different conditions have supported the foundry show. Amongst these are Asea Electric Company, of 5, Chancery Lane, W.C.2; W. & T. Avery, Limited, Soho Foundry, Birmingham; Babcock & Wilcox, Limited, Farringdon Street, E.C.4; Birmingham Electric Furnaces, Limited, Tyburn Road, Birmingham; Black & Decker, Limited, Slough; British Oxygen Company, Victoria Station House, Westminster, S.W.1; Desoutter Bros., Limited, The Hyde, Hendon, N.W.9; Flextol Engineering Company, Limited, 18, Dartmouth Street, S.W.1; G.W.B. Electric Furnaces, Limited, North Road, Holloway, N.7; Hancock & Company (Engineers), Limited, Progress Way, Croydon, Surrey; Major, Robinson & Company, Limited, City Road, Cornbrook, Manchester; Mond Nickel Company, Limited, Thames House, Millbank, S.W.1; Murex Welding Processes, Limited, Ferry Lane Works, Walthamstow, E.17; New Process Welders, Limited, Scotts Road, Southall, Middlesex; Phillips Industrial, 145, Charing Cross Road, S.E.1; Reaveil & Company, Limited, Ranelagh Works, Ipswich; Tensometer, Limited, 73, Southampton Row, W.C.1; Wild, Barfield Electric Furnaces, North Road, Holloway, N.7; Carl Zeiss (London), Limited, Mortimer House, Mortimer Street, W.1; Felco Hoists, Limited, 17, Victoria Street, S.W.1; Foster Instruments Company, Letchworth; F. Gilman (B.S.T.), Limited, 221, High Street, Smethwick, Staffs; Broom & Wade, Limited, High Wycombe; Dominion Machinery Company, Limited, Hipperholme, Halifax; Shell-Mex & B.P., Limited, Shell-Mex House, Victoria Embankment, London, W.C.2. In addition to the list of exhibitors in the Foundry Exhibition proper published in our issue of March 28, the following have now taken space: Appleby-Frodingham Steel Company, Limited, Scunthorpe, Lincs; Coleman Foundry Equipment Company, Limited, 156, Strand, W.C.2; T. J. Priestman, 94, Leopold Street, Birmingham, 12, and United Steel Companies, Limited, 17, Westbourne Road, Sheffield, 10.

Obituary

Mr. Alfred Rhodes, a director and formerly works manager of Messrs. Calvert & Company, Limited, ironfounders, of Huddersfield, died recently.

Mr. James Rae, who has died at the age of 81, served in the moulding department of the Falkirk Iron Company for over 60 years. In 1918, after he had completed half a century's service, he was presented with a gold watch. He retired from active work a few years ago.

Mr. John Kitching has died at Darlington, at the age of 81. For the greater part of his career, Mr. Kitching was associated with the working of railways in Great Britain and Spain. He was a member of the Iron and Steel Institute and of the Cleveland Institute of Engineers.

The Brasshouse Engineering Company, Limited, is being wound up voluntarily. Mr. John Ash Garland, 148, Edmund Street, Birmingham, is the liquidator.

According to Mr. A. Hartland's Report on the Economic Conditions in British Malaya, published by H.M. Stationery Office, Kingsway, London, W.C.2 (price 2s. 6d.), the Japanese share in cast-iron pipes advanced from 1.8 per cent. in 1932 to 40.2 in 1934. Competition is also experienced from India. He also states that the hollow-ware trade is rapidly becoming a Japanese monopoly.

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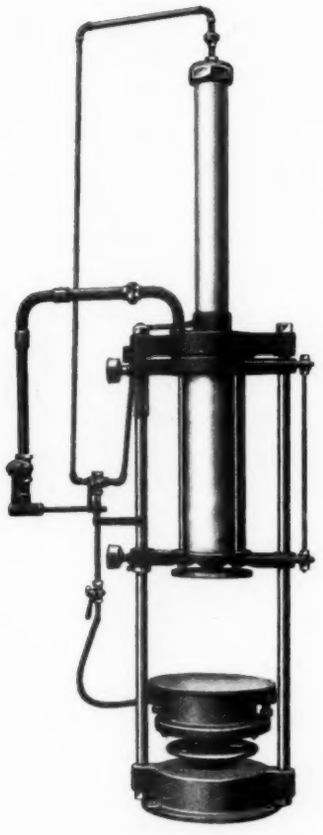

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Raw Material Markets

Rather more activity has been witnessed in the home iron and steel markets during the past week, a number of contract renewals having been negotiated. There is, generally speaking, a strong demand for pig-iron at the moment, foundry iron being in slightly improved request. Export trade is still in a far from flourishing state. The precise effects of the devaluation of the belga have yet to be determined, but it has, at all events, placed the Belgian exporters in a favourable position in the world's markets.

Pig-Iron

MIDDLESBROUGH.—The Cleveland iron trade has been fairly busy during the past week, the activity being confined to the home market, however. There has been a stronger demand from local foundries, and Scottish consumers have also called for increased deliveries. Export prices are unregulated and show considerable variation, but uniform rates govern the home trade, No. 3 Cleveland G.M.B. being quoted at 67s. 6d. per ton delivered Middlesbrough, 69s. 6d. delivered North-East Coast, 67s. 3d. at Falkirk, and 70s. 3d. at Glasgow.

Although the export demand for East Coast hematite continues to fall away, this has been offset by the stronger call from the home market, in particular from South Wales. Steelworks consumption of hematite is steady and prices unchanged, quotations for No. 1 quality in the principal zones being 69s. per ton delivered Middlesbrough, 71s. delivered North-East Coast, 76s. delivered Lancashire, and 79s. delivered Birmingham.

LANCASHIRE.—The Midland ironmasters report that the consumption of pig-iron in this area is maintained at a fairly good level, but that hopes of a seasonal expansion have not so far been fully realised, especially as regards the light-castings trade. An improvement in this direction is confidently looked for, however. The market is steady, with offers of Staffordshire, Derbyshire and Lancashire brands of No. 3 foundry iron, equal to Derbyshire, at 74s. per ton for delivery in the Lancashire zone, Northamptonshire being quoted at 72s. 6d., Derbyshire forge material at 69s., Scottish No. 3 foundry at about 82s. 6d., West Coast hematite at about 78s. 6d., and East Coast at from 75s. to 76s.

MIDLANDS.—Conditions in this market show little change, the supply of foundry iron being ample to meet the current demand. Little new buying has taken place, the majority of consumers being under contract till the end of June. In this connection, it is stated that unless business accelerates at a greater rate than is at present apparent, full supplies will not have been taken out by that time. The controlled rates for ordinary Midland brands of foundry iron are 67s. 6d. per ton for Northants No. 3 and 71s. per ton for Derbyshire, Lincolnshire and North Staffordshire No. 3, delivered Birmingham and Black Country stations, these prices being subject to a small graduated rebate to large consumers. The current quotations for medium-phosphorus pig-iron range from 72s. up to 80s., low-phosphorus, including Scottish No. 3, from 85s. to 87s. 6d., and special refined pig-iron from £5 7s. 6d. to £7, delivered Midland points.

SCOTLAND.—Activity in the Glasgow iron market is largely confined to steelmaking irons, the small foundries continuing to report a lack of business. There is no alteration in the minimum fixed prices, viz., 70s. f.o.t. furnaces for No. 3 foundry and 2s. 6d. per ton extra for No. 1. The Falkirk light-castings trade is active. Official figures show that the Tees sent 7,659 tons of foundry iron to Scotland last month, and in addition to this local makers were delivering steady tonnages of similar iron. There is no change in the official quotations for Cleveland foundry iron, viz., 67s. 3d. f.o.t. Falkirk and 70s. 3d. f.o.t. Glasgow for No. 3 quality. Other English irons are quoted at 1s. 3d. per ton below these figures.

Coke

Prices are firmly held in the foundry-coke market, but there is little new business because the majority of users are well contracted forward. Current quotations for delivery in the Birmingham district are as follow:—Best Durham coke, 36s. to 40s.; Welsh coke, 34s. to 43s. 6d. per ton, according to analysis and tonnage.

Steel

Rather quieter trading conditions have developed in the steel markets and there seems to be an inclination on the part of buyers to adopt a cautious policy. To some extent this may be due to the approaching meeting between the British and Continental steelmakers, which is likely to result in an arrangement regarding a quota for the British market. The devaluation of the belga, also, has not been without its influence upon British buyers, and there is a natural disposition to wait until the situation becomes clearer. The activity in the semi-finished steel department has become less pronounced. A considerable tonnage of orders, however, was placed with the British works during the recent buying movement, and most consumers have now covered their requirements for some time. Deliveries continue to be on a satisfactory scale and this branch of the industry can look forward to busy conditions. Business in finished steel is still somewhat irregular: but in most departments there is a tendency for the demand to expand. There has been a slight revival lately on the export side of the market, but conditions remain difficult.

Scrap

There is an active demand for cast-iron scrap in the Cleveland district. Good machinery metal in suitable sizes can be sold at 55s., and up to 53s. per ton has been paid by keen buyers for heavy foundry metal. A steady demand is reported in the Midlands, where heavy machinery metal broken into handy sizes is at 55s. to 57s. 6d., according to quality, good heavy at 50s. and clean light scrap at 47s. 6d., all delivered works. In South Wales, heavy cast iron in large pieces and furnace sizes is quiet at 50s. to 52s., and good cast-iron machinery scrap is only in limited demand at 52s. 6d. to 55s., as the local consumption is small. In Scotland, heavy machinery cast-iron scrap in cupola sizes is changing hands at 56s. 6d., with ordinary cast-iron scrap to the same specification 52s.

Metals

Copper.—The distinctly stronger tone noticeable in the copper market is, of course, largely based on the forthcoming restriction of production, as arranged for at the New York conference. At the same time, there seems to have been a definite increase in consumptive buying, and it is said that a good part of this can be ascribed to activity in the armaments industry on the Continent. Quotations on the London Metal Exchange this week reached a new high level for the year.

Daily quotations:—

Cash.—Thursday, £31 1s. 3d. to £31 2s. 6d.; Friday, £31 3s. 9d. to £31 5s.; Monday, £31 15s. to £31 16s. 3d.; Tuesday, £31 13s. 9d. to £31 15s.; Wednesday, £31 10s. to £31 11s. 3d.

Three Months.—Thursday, £31 10s. to £31 11s. 3d.; Friday, £31 12s. 6d. to £31 13s. 9d.; Monday, £32 2s. 6d. to £32 5s.; Tuesday, £32 2s. 6d. to £32 3s. 9d.; Wednesday, £31 18s. 9d. to £32.

Tin.—Tin prices now seem to have recovered from their recent heavy fall, and the market is once again confident.

"Trade demand in this country has slackened a little following the rather quieter conditions which have obtained in the tinplate industry in South Wales, but a moderate demand is reported from the Continent, whilst in the United States buying has been resumed on a more substantial scale, following the improvement in consuming industries there. The market in London has reflected the more favourable statistical position disclosed, as also the improved demand in the U.S.A., in consequence of which sellers have displayed a good deal of reserve," report Messrs. Rudolf Wolff & Company.

Market fluctuations:—

Cash.—Thursday, £222 10s. to £223 10s.; Friday, £223 to £223 10s.; Monday, £223 15s. to £224; Tuesday, £224 10s. to £224 15s.; Wednesday, £223 5s. to £223 15s.

Three Months.—Thursday, £219 10s. to £219 15s.; Friday, £219 15s. to £220; Monday, £219 10s. to £219 15s.; Tuesday, £220 15s. to £221; Wednesday, £219 15s. to £220.

Spelter.—It is stated that a new scheme is being prepared for re-casting the present import duties on spelter and lead. As reported last week, the first scheme, although it had the support of the principal producers and consumers and the London Metal Exchange, was rejected by the Import Duties Advisory Committee. The news that a scheme more likely to be accepted is now being drawn up caused the market to strengthen, and prices again rose sharply.

Official quotations:—

Ordinary.—Thursday, £12 15s.; Friday, £13; Monday, £13; Tuesday, £12 17s. 6d.; Wednesday, £12 16s. 3d.

Lead.—The possibility of the import-duty position being amended, as referred to above, has caused sellers to hold back. At the same time, there has been a good demand from the consuming trades in this country.

Day-to-day prices:—

Soft Foreign (Prompt).—Thursday, £12 2s. 6d.; Friday, £12 5s.; Monday, £12 3s. 9d.; Tuesday, £12 1s. 3d.; Wednesday, £12 1s. 3d.

Factors to Increase Production in Enamelling Plants

(*Concluded from page* 248.)

Mr. Kent replied that he did not think the operations of the Sterling Company and the Singer Company could be compared. For instance, probably they were not using air at the same high pressures.

Mr. Roberts said he thought the Singer Company used a pressure of 80 to 90 lbs. per sq. in.

Mr. Kent thought that the apertures of the boron carbide and other nozzles were often too small when they were first used, and the operators had objected to using them.

Mr. Roberts replied that certain manufacturers would make any size of aperture required and any size of inlet at the back-end of the nozzle. One firm had made them to the specification submitted by his company.

Mr. Kent said all that had been supplied to the Sterling Company had been too small; there was a shoulder inside, which created a kind of whirlwind of shot, and jamming had occurred.

Mr. J. T. Gray referred to an alloy nozzle of which he had had considerable experience; it was guaranteed for 600 hrs., at 60 lbs. pressure. One firm in this country, which owned a number of enamelling plants and had a very accurate costing system, had compared the cost of using these nozzles against the cost of using chilled nozzles made in their own foundry and costing 1½d. apiece. With the special-alloy nozzle they could run for 600 hrs. without shutting down to change the nozzle, and they had found that the cost of 600 hours' working with the chilled nozzles was 2½d. greater.

On the motion of Mr. W. H. Whittle (chairman and Vice-President of the Institute), thanks were accorded Mr. Kent for his Paper; and Messrs. Stewart & Company for having given the members facilities to visit their works that afternoon, as well as for their hospitality.

Improvement in Scottish Foundry Trade

An optimistic note is struck in the annual report of the General Iron Fitters' Association of Scotland, issued at Falkirk recently. The report states that in November last the lowest number of unemployed was recorded. The figures at present are still below those of a year ago and of the last four years prior thereto. They include all sections and all branches. It is stated that as to the future there is no reason to worry. Falkirk is covering the light-castings industry, and is looking forward to a fair share in the orders arising out of the anticipated housing impetus of 1935. Glasgow and Kirkintilloch, covering engineering and general founding, report only two dozen unemployed. Bonnybridge reports trade as good at present and prospects equally good. The only word of gloom that the report contains is in connection with Bo'ness, where trade is stated to be poor, with prospects equally so.

Sterling

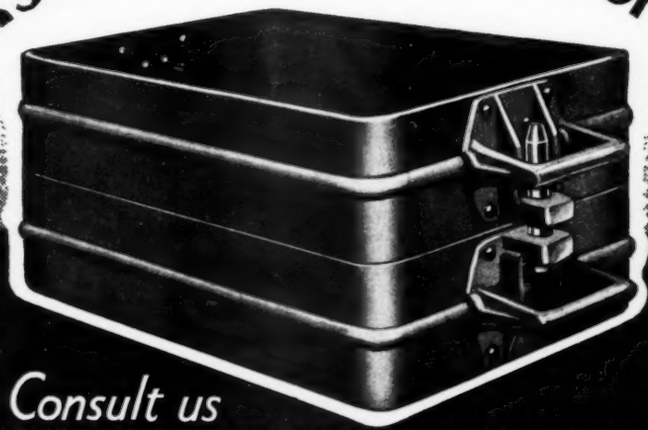
MOULDING BOXES

ARE THE GREATEST ECONOMY
YOU CAN INTRODUCE INTO
YOUR FOUNDRY

•

THEY SPEED UP PRODUCTION
PRODUCE BETTER CASTINGS
SAVE UNNECESSARY LABOUR

OVER 30 STANDARD DESIGNS OF BOXES



Consult us
AND LET US SOLVE YOUR MOULDING BOX PROBLEMS—

STERLING FOUNDRY SPECIALTIES LTD
BEDFORD
LONDON OFFICE: 13 VICTORIA STREET · WESTMINSTER · S.W.1

RAW MATERIALS—PRICE LIST

(Wednesday, April 10, 1935)

COPPER

	£ s. d.
Standard cash	31 10 0
Three months	31 18 9
Electrolytic	35 0 0
Tough	33 15 0
Best selected	34 5 0
Sheets	60 0 0
India	45 10 0
Wire bars	35 15 0
Ingot bars	35 15 0
H.C. wire rods	38 10 0
Off. av. cash, March	28 11 0⅝
Do., 3 mths., March	28 18 2½
Do., Sttlmnt., March	28 10 11½
Do., Electro, March	31 16 10½
Do., B.S., March	31 9 2
Do., wire bars, March	32 1 6½
Solid drawn tubes	9¾d.
Brazed tubes	9¾d.
Wire	6¼d.

BRASS

Solid drawn tubes	9d.
Brazed tubes	11d.
Rods, drawn	8¼d.
Rods, extd. or rlld.	4¼d.
Sheets to 10 w.g.	7⅜d.
Wire	7¼d.
Rolled metal	6¾d.
Yellow metal rods	4¼d.
Do. 4 × 4 Squares	5½d.
Do. 4 × 3 Sheets	5½d.

TIN

	£ s. d.
Standard cash	223 5 0
Three months	219 15 0
English	224 0 0
Bars	225 12 6
Straits	229 5 0
Australian (nom.)	—
Eastern	225 5 0
Banca	231 5 0
Off. av. cash, March	215 19 5⅞
Do., 3 mths., March	211 17 1⅝
Do., Sttlmt., March	215 18 9⅝

SPELTER

	£ s. d.
Ordinary	12 16 3
Remelted	13 10 0
Hard	11 0 0
Electro 99.9	15 10 0
English	14 2 6
India	12 10 0
Zinc dust	17 0 0
Zinc ashes	3 0 0
Off. aver., March	12 3 5⅞
Aver. spot, March	12 1 10⅝

LEAD

	£ s. d.
Soft foreign ppt.	12 1 3
Empire (nom.)	13 3 9
English	14 0 0
Off. average, March	11 1 11 13/16
Average spot, March	11 0 2⅜

ALUMINIUM

Ingots	£100 to £105
Wire	1/1 to 1/9 lb.
Sheet and foil	1/2 to 2/9 lb.

ZINC SHEETS, &c.

	£ s. d.
Zinc sheets, English	22 10 0
Do., V.M. ex-whse.	23 2 6
Rods	27 15 0

ANTIMONY

	£ s. d.
English	79 0 0 to 80 0 0
Chinese, ex-whse., (nom.)	67 0 0
Crude	—

QUICKSILVER

	£ s. d.
Quicksilver	11 7 6 to 11 17 6

FERRO-ALLOYS AND STEEL-MAKING METALS

Ferro-silicon—	
25%	8 17 6
45/50%	12 15 0
75%	17 17 6
Ferro-vanadium—	
35/50	12/8 lb. Va.
Ferro-molybdenum—	
70/75% carbon-free	4/6 lb. Mo.
Ferro-titanium—	
23/25% carbon-free	9d. lb.
Ferro-phosphorus, 20/25%	£15 15 0
Ferro-tungsten—	
80/85%	3/- lb.
Tungsten metal powder—	
98/99%	3/3 lb.
Ferro-chrome—	
2/4% car.	31 10 0
4/6% car.	21 15 0
6/8% car.	21 10 0
8/10% car.	21 10 0
Ferro-chrome—	
Max. 2% car.	34 0 0
Max. 1% car.	36 5 0
Max. 0.70% car.	37 5 0
70% carbon-free	9¾d. lb.
Nickel—99.5/100%	£200 to £205
"F" nickel shot	£184 0 0
Ferro-cobalt, 98/99%	5/- to 5/6 lb.
Metallic chromium—	
96/98%	2/5 lb.
Ferro-manganese (net)—	
76/80% loose	£10 15 0 to £11 5 0
76/80% packed	£11 15 0 to £12 5 0
76/80% export	(nom.) £9 15 0
Metallic manganese—	
94/96% carbon-free	1/3 lb.

Per ton unless otherwise stated.

HIGH-SPEED TOOL STEEL

Finished bars, 14% tungsten	2s. 0d
Finished bars, 18% tungsten	2s. 9d

Per lb. net, d/d buyers' works.

Extras—	
Rounds and squares, 3 in. and over	4d. lb.
Rounds and squares, under ½ in. to ¼ in.	3d. lb.
Do., under ¼ in. to 3/16 in.	1/- lb.
Flats, ½ in. × ¼ in. to under 1 in. × ⅜ in.	3d. lb.
Do., under ½ in. × ¼ in.	1/- lb.
Bevels of approved sizes and sections	6d. lb.

Bars cut to length, 10% extra.

SCRAP

South Wales—	£ s. d.	£ s. d.
Heavy steel	2 15 0	to 2 16 0
Bundled shrngs.		2 7 6
Mixed iron and steel	2 10 0	to 2 12 0
Heavy cast iron	2 10 0	to 2 12 0
Good machinery	2 12 6	to 2 15 0
Cleveland—		
Heavy steel	2 11 6	to 2 12 6
Steel turnings		1 15 0
Cast-iron borings		1 5 0
Heavy cast iron		2 13 0
Heavy machinery		2 15 0
Midlands—		
Light cast-iron scrap		2 7 6
Heavy wrought iron	2 17 6	to 3 0 0
Steel turnings, f.o.r.		1 14 0
Scotland—		
Heavy steel		2 10 0
Ordinary cast iron		2 12 0
Engineers' turnings		1 19 6
Cast-iron borings		1 18 0
Wr'ght-iron piling		2 17 0
Heavy machinery		2 16 6

London—Merchants' buying prices, delivered yard.

	£ s. d.
Copper (clean)	26 0 0
Brass	17 10 0
Lead (less usual draft)	10 10 0
Tea lead	7 15 0
Zinc	9 0 0
New aluminium cuttings	66 0 0
Braziery copper	22 0 0
Gunmetal	24 0 0
Hollow pewter	152 0 0
Shaped black pewter	105 0 0

PIG-IRON

N.E. Coast (d/d Tees-side area)—	
Foundry No. 1	70/-
Foundry No. 3	67/6
,, at Falkirk	67/3
,, at Glasgow	70/3
Foundry No. 4	66/6
Forge No. 4	66/6
Hematite No. 1	69/-
Hematite M/Nos.	68/6
N.W. Coast—	
Hem. M/Nos. d/d Glas.	72/6
,, d/d Birm.	84/6
Malleable iron d/d Birm.	115/-
Midlands (d/d Birmingham dist.)—	
Staffs No. 4 forge	67/-
,, No. 3 fdry.	71/-
Northants forge	63/6
,, fdry. No. 3	67/6
,, fdry. No. 1	70/6
Derbyshire forge	67/-
,, fdry. No. 3	71/-
,, fdry. No. 1	74/-
Scotland—	
Foundry No. 1, f.o.t.	72/6
,, No. 3, f.o.t.	70/-
Hem. M/Nos. d/d	71/-
Sheffield (d/d district)—	
Derby forge	64/6
,, fdry. No. 3	68/6
Lincs forge	64/6
,, fdry. No. 3	68/6
E.C. hematite	81/6
W.C. hematite	83/6
Lancashire (d/d eq. Man.)—	
Derby fdry. No. 3	74/-
Staffs fdry. No. 3	74/-
Northants fdry. No. 3	72/6
Cleveland fdry. No. 3	74/-
Dalzell, No. 3 (special)	102/6 to 105/-
Glengarnock, No. 3	82/6
Clyde, No. 3	82/6
Monkland, No. 3	82/6
Summerlee, No. 3	82/6
Eglinton, No. 3	82/6
Gartsherrie, No. 3	82/6
Shotts, No. 3	82/6

FINISHED IRON AND STEEL

Usual district deliveries for iron; delivered consumer's station for steel.

Iron—	£ s. d.	£ s. d.
Bars (cr.)	9 12 6	to 9 15 0
Nut and bolt iron	7 10 0	to 8 0 0
Hoops	10 10 0	and up.
Marked bars (Staffs) f.o.t.	12 0 0	
Gas strip	10 10 0	and up.
Bolts and nuts, ¾ in. × 4 in.	14 2 6	and up.
Steel—		
Plates, ship, etc.	8 15 0	to 8 17 6
Boiler plts.	9 5 0	to 9 7 6
Chequer plts.	10 7 6	
Angles	8 7 6	
Tees	9 7 6	
Joists	8 15 0	
Rounds and squares, 3 in. to 5½ in.	9 7 6	
Rounds under 3 in. to ⅝ in. (Untested)	8 12 0	
Flats—8 in. wide and over	8 12 6	
,, under 8 in. and over 5 in.	8 17 6	
Rails, heavy	8 5 0	to 8 10 0
Fishplates	12 5 0	to 12 10 0
Hoops (Staffs)	9 7 0	
Black sheets, 24g. (4-t. lots)	10 10 0	
Galv. cor. shts. (,,)	13 0 0	
Galv. flat shts. (,,)	13 10 0	
Galv. fencing wire, 8g. plain	14 10 0	
Billets, soft	5 10 0	and up.
Billets, hard	6 17 6	to 7 2 6
Sheet bars	5 0 0	to 5 7 6
Tin bars	5 2 6	to 5 7 6

PHOSPHOR BRONZE

	Per lb. basis.
Strip	9¾d.
Sheet to 10 w.g.	10¾d.
Wire	11¾d.
Rods	10¾d.
Tubes	13¾d.
Castings	12d.

Delivery 3 cwt. free.
10% phos. cop. £30 above B.S.
15% phos. cop. £35 above B.S.
Phosphor tin (5%) £30 above price of English ingots.
C. Clifford & Son, Limited.

NICKEL SILVER, &c.

	Per lb.
Ingots for raising	7d. to 1/1
Rolled—	
To 9 in. wide	1/1 to 1/7
To 12 in. wide	1/1½ to 1/7¼
To 15 in. wide	1/1⅝ to 1/7½
To 18 in. wide	1/2 to 1/8
To 21 in. wide	1/2½ to 1/8½
To 25 in. wide	1/3 to 1/9
Ingots for spoons and forks	7d. to 1/3½
Ingots rolled to spoon size	10d. to 1/6½
Wire round—	
to 10g.	1/4½ to 1/11½

with extras according to gauge.
Special 5ths quality turning rods in straight lengths, 1/3½ upwards.

AMERICAN IRON AND STEEL

At Pittsburgh unless otherwise stated.

	Dols.
No. 2 foundry, Phila.	20.26
No. 2 foundry, Valley	18.50
No. 2 foundry, Birm.	14.50
Basic, Valley	18.00
Bessemer	20.76
Malleable, Valley	18.50
Grey forge, Valley	18.00
Ferro-mang. 80%, seaboard	85.00
O.-h. rails, h'y, at mill	36.37½
Billets	27.00
Sheet bars	28.00
Wire rods	38.00
	Cents.
Iron bars, Chicago	1.80
Steel bars	1.80
Tank plates	1.80
Beams, etc.	1.80
Skelp, grooved steel	1.70
Steel hoops	2.10
Sheets, black, No. 24	2.40
Sheets, galv., No. 24	3.10
Wire nails	2.60
Plain wire	2.30
Barbed wire, galv.	3.00
Tinplates, 100-lb. box	$5.25

COKE (at ovens)

Welsh foundry	25/- to 30/-
,, furnace	19/- to 20/-
Durham foundry	19/- to 22/-
,, furnace	16/6 to 17/9
Midlands, foundry	—
,, furnace	—

TINPLATES

f.o.b. Bristol Channel ports.

I.C. cokes	20×14 per box	18/2 to 19/2
,,	28×20 ,,	36/4 to 38/3
,,	20×10 ,,	26/- to 26/9
,,	18¾×14 ,,	18/6 to 18/4
C.W.	20×14 ,,	15/6 to 16/6
,,	28×20 ,,	33/- to 33/6
,,	20×10 ,,	23/- to 24/-
,,	18¾×14 ,,	16/- to 17/-

SWEDISH CHARCOAL IRON & STEEL

	£ s. d.	£ s. d.
Pig-iron	£6 0 0	to £7 0 0
Bars-hammered, basis	£16 0 0	to £16 10 0
Bars and nail-rods, rolled, basis	£15 15 0	to £16 0 0
Blooms	£10 0 0	to £12 0 0
Keg steel	£30 0 0	to £31 0 0
Faggot steel	£18 0 0	to £23 0 0
Bars and rods dead soft, st'l	£10 0 0	to £12 0 0

All per English ton, f.o.b. Gothenburg.
[Subject to an exchange basis of Kr. 18.16 to £1.]

DAILY FLUCTUATIONS

Standard Copper (cash)

		£	s.	d.		
Apr. 4 ..	31	1	3	inc.	16/3
.. 5 ..	31	3	9	,,	2/6
,, 8 ..	31	15	0	,,	11/3
,, 9 ..	31	13	9	dec.	1/3
,, 10 ..	31	10	0	,,	3/9

Electrolytic Copper

		£	s.	d.		
Apr. 4 ..	34	10	0	inc.	15/-
.. 5 ..	34	10	0	No	change
.. 8 ..	35	5	0	inc.	15/-
.. 9 ..	35	5	0	No	change
,, 10 ..	35	0	0	dec.	5/-

Standard Tin (cash)

		£	s.	d.		
Apr. 4 ..	222	10	0	inc.	100/-
,, 5 ..	223	0	0	,,	10/-
,, 8 ..	223	15	0	,,	15/-
,, 9 ..	224	10	0	,,	15/-
,, 10 ..	223	5	0	dec.	25/-

Tin (English ingots)

		£	s.	d.		
Apr. 4 ..	223	5	0	inc.	110/-
.. 5 ..	223	15	0	,,	10/-
,, 8 ..	224	5	0	,,	10/-
,, 9 ..	225	0	0	,,	15/-
,, 10 ..	224	0	0	dec.	20/-

Spelter (ordinary)

		£	s.	d.		
Apr. 4 ..	12	15	0	inc.	11/3
,, 5 ..	13	0	0	,,	5/-
,, 8 ..	13	0	0	No	change
,, 9 ..	12	17	6	dec.	2/6
,, 10 ..	12	16	3	,,	1/3

Spelter (Electro, 99.9 per cent.)

		£	s.	d.		
Apr. 4 ..	15	7	6	inc.	12/6
.. 5 ..	15	12	6	,,	5/-
,, 8 ..	15	12	6	No	change
,, 9 ..	15	10	0	dec.	2/6
,, 10 ..	15	10	0	No	change

Zinc Sheets (English)

		£	s.	d.		
Apr. 4 ..	22	10	0	inc.	5/-
,, 5 ..	22	12	6	,,	2/6
,, 8 ..	22	12	6	No	change
,, 9 ..	22	10	0	dec.	2/6
,, 10 ..	22	10	0	No	change

Lead (English)

		£	s.	d.		
Apr. 4 ..	14	0	0	inc.	5/-
.. 5 ..	14	0	0	No	change
,, 8 ..	14	0	0	,,	,,
,, 9 ..	14	0	0	,,	,,
,, 10 ..	14	0	0	,,	,,

AVERAGE MONTHLY PRICES OF STEEL BOILER PLATES IN ENGLAND

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly average
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1898	6 10 0	6 8 9	6 8 9	6 10 0	6 15 0	6 18 9	6 17 6	6 17 6	7 2 6	6 15 0	7 0 0	7 5 0	6 15 8½
1899	7 5 0	8 0 0	8 2 6	8 2 6	8 5 0	8 5 0	8 12 6	8 12 6	8 15 0	8 15 0	9 2 6	9 5 0	8 17 8½
1900	9 5 0	9 5 0	9 7 6	9 10 0	9 12 6	10 5 0	10 5 0	10 5 0	10 5 0	10 0 0	9 15 0	9 15 0	9 15 10
1901	9 5 0	9 5 0	8 15 0	8 10 0	8 10 0	7 10 0	7 15 0	7 15 0	7 15 0	7 15 0	7 15 0	7 15 0	8 3 11
1902	7 7 6	7 0 0	7 12 6	7 12 6	7 12 6	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 9 7
1903	7 10 0	7 10 0	7 15 0	7 5 0	7 5 0	7 5 0	7 5 0	7 0 0	7 0 0	7 0 0	7 0 0	6 17 6	7 3 11½
1904	6 12 6	6 15 0	7 0 0	7 0 0	7 0 0	7 0 0	7 0 0	7 0 0	7 0 0	7 0 0	7 0 0	7 0 0	6 18 11½
1905	6 17 6	6 17 6	6 17 6	6 17 6	6 17 6	6 17 6	6 17 6	6 17 6	6 10 0	7 5 0	8 0 0	8 0 0	7 1 3
1906	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 10 0	8 0 10
1907	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 0 0	8 0 0	8 8 4
1908	7 10 0	7 10 0	7 10 0	7 5 0	7 5 0	7 5 0	7 0 0	7 0 0	7 0 0	7 0 0	7 0 0	7 0 0	7 3 9
1909	7 0 0	7 0 0	7 0 0	7 0 0	7 0 0	6 15 0	6 15 0	6 15 0	7 0 0	7 0 0	7 0 0	7 0 0	6 18 9
1910	7 0 0	7 0 0	7 1 3	7 5 0	7 5 0	7 5 0	7 5 0	7 5 0	7 5 0	7 10 0	7 10 0	7 10 0	7 5 1
1911	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 14 0	7 10 4
1912	7 18 9	8 0 0	8 0 0	8 7 6	8 10 0	8 10 0	8 10 0	8 15 0	8 16 3	9 0 0	9 2 0	9 5 0	8 11 2½
1913	9 5 0	9 5 0	9 5 0	9 5 0	9 5 0	9 5 0	9 5 0	8 19 0	8 15 0	8 5 0	7 15 0	7 15 0	8 17 0
1914	7 15 0	7 15 0	7 15 0	7 13 9	7 10 6	7 5 0	7 0 0	8 0 0	8 2 6	8 5 0	8 5 0	8 5 0	7 15 11½
1915	8 14 0	9 10 0	9 17 6	10 10 0	10 10 0	11 0 0	11 0 0	11 0 0	11 0 0	11 4 0	12 0 0	13 0 0	10 15 5½
1916	13 0 0	13 0 0	13 0 0	12 15 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 12 11
1917	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0
1918	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0
1919	13 0 0	15 0 0	15 0 0	15 0 0	19 5 0	19 17 6	21 0 0	21 10 0	21 10 0	21 10 0	21 15 0	23 10 0	18 9 9
1920	26 0 0	28 0 0	28 5 0	28 10 0	29 5 0	30 0 0	30 0 0	30 0 0	30 10 0	31 0 0	31 0 0	31 0 0	29 9 2
1921	30 5 0	29 0 0	25 0 0	25 0 0	25 0 0	23 0 0	21 0 0	20 10 0	19 0 0	17 10 0	16 0 0	14 16 0	22 1 9
1922	14 15 0	14 10 0	14 10 0	14 10 0	14 10 0	13 1 8	13 10 0	12 15 0	12 10 0	12 10 0	12 10 0	12 6 0	13 10 9
1923	12 8 9	13 6 0	14 0 0	14 0 0	14 0 0	14 0 0	13 12 6	13 0 0	13 0 0	13 0 0	13 0 0	13 10 0	13 9 1½
1924	13 10 0	13 10 0	13 10 0	13 10 0	13 10 0	13 10 0	13 10 0	14 0 0	14 0 0	13 11 0	13 5 0	13 5 0	13 10 11
1925	13 5 0	13 5 0	13 5 0	13 1 0	12 15 0	12 15 0	12 15 0	12 15 0	12 7 6	11 14 0	11 10 0	11 10 0	12 11 5½
1926	11 10 0	11 10 0	11 10 0	11 5 0	11 5 0	11 5 0	11 5 0	11 5 0	11 5 0	11 5 0	11 5 0	11 5 0	11 6 3
1927	11 5 0	11 5 0	11 5 0	11 5 0	11 2 6	11 0 0	11 0 0	11 0 0	10 16 0	10 10 0	10 10 0	10 16 0	10 19 0½
1928	10 10 0	10 10 0	10 10 0	10 10 0	10 10 0	10 10 0	10 10 0	10 10 0	10 10 0	10 10 0	10 10 0	10 10 0	10 10 0
1929	10 10 0	10 10 0	10 10 0	10 10 0	10 10 0	10 10 0	10 10 0	10 5 0	10 1 3	10 1 3	10 1 3	10 1 7	10 6 8½
1930	10 2 9	10 3 5½	10 3 9	10 3 9	10 3 6	10 2 6	10 2 6	10 2 6	10 2 2½	9 19 6	9 16 3	9 16 3	10 1 6½
1931	9 15 0	9 15 0	9 15 0	9 10 11	9 6 9	9 5 0	9 7 0	9 7 9½	9 8 9	9 5 9	9 5 6	9 9 6	9 9 4
1932	9 5 0	9 2 6	8 18 6	8 17 6	8 16 6½	8 16 3	8 16 3	8 16 3	8 16 3	8 16 3	8 16 3	8 16 3	8 17 10
1933	8 10 0	8 10 0	8 10 0	8 8 9	8 5 0	8 5 0	8 5 0	8 5 0	8 5 0	8 5 0	8 6 0	8 7 6	8 6 10½
1934	8 8 1½	8 10 7½	8 16 6	8 17 6	8 6 3	8 6 3	8 5 7½	8 5 0	8 5 0	8 5 0	9 6 3	9 6 3	8 11 6½
1935	9 6 3	9 6 3	9 6 3	—	—	—	—	—	—	—	—	—	—

WILLIAM JACKS & COMPANY,

WINCHESTER HOUSE, OLD BROAD ST., LONDON, E.C.2.

CLARENCE CHAMBERS, 39, CORPORATION STREET, BIRMINGHAM.

13, RUMFORD STREET, LIVERPOOL.

PIG IRON

REGISTERED TRADE MARK

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All grades FOUNDRY, HEMATITE, BASIC, SPECIALS, &c.

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